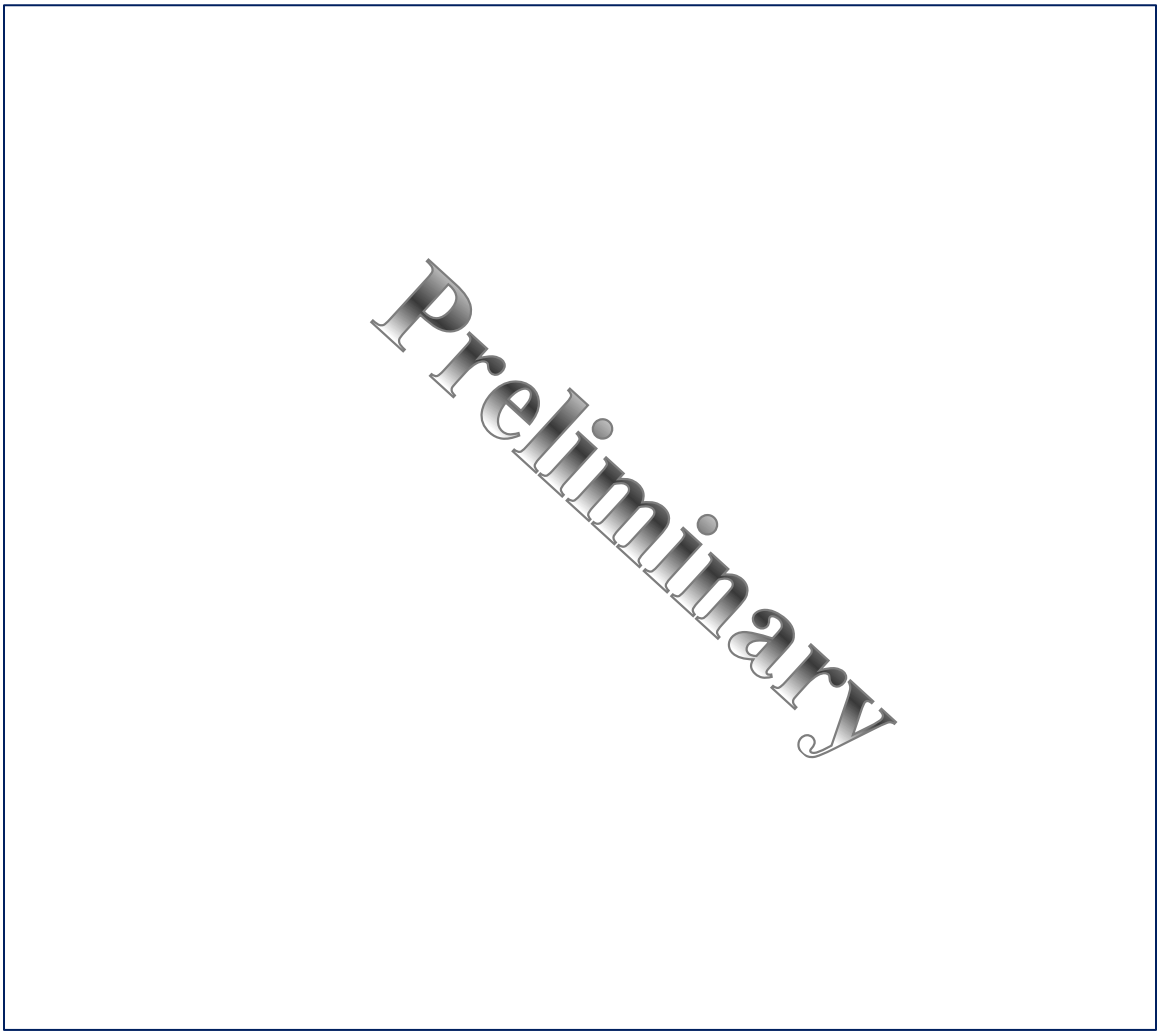
BGA244 Binary Gas Analyzer

User Manual



Stanford Research Systems

Certification

Stanford Research Systems certifies that this product met its published specification at the time of shipment.

Warranty

This Stanford Research Systems product is warranted against defects in materials and workmanship for a period of one (1) year from the date of shipment.

Service

For warranty service or repair, this product must be returned to a Stanford Research Systems authorized service facility. Contact Stanford Research Systems or an authorized representative for a RMA (Return Material Authorization) Number before returning this product for repair. These are available at *www.thinksrs.com* under Support, Repair/Calibration.

All users returning a BGA244 back to the factory for repair and/or service must submit a correctly completed "Declaration of Contamination of Equipment" form, available as part of the RMA process. The SRS personnel carrying out repair and service of the BGA244 must be informed of the condition of the components prior to any work being performed.

Warning

All returns to SRS must be free of harmful, corrosive, radioactive or toxic materials.

Dedication

In memory of Jim Williams, 1948 - 2011: Legendary Analog Design Guru and Author

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Safety Procedures and Precautions

Observe the following general safety precautions during all phases of operation of this instrument. Failure to comply with these precautions or with other specific warnings elsewhere in this manual violates the safety standards of intended use of this instrument and may impair the protection provided by the equipment. Stanford Research Systems, Inc. assumes no liability for the customer's failure to comply with these requirements.

DO NOT SUBSTITUTE PARTS OR MODIFY THE INSTRUMENT
Do not install substitute parts or perform any unauthorized modification to the instrument. Return the instrument to Stanford Research Systems or an authorized representative for service and repair to ensure all safety features are maintained.

SERVICE BY QUALIFIED PERSONNEL ONLY
Operating personnel should not attempt any component replacement or internal adjustments. Any service should be performed by qualified service personnel only.

USE CAUTION WHEN OPERATING WITH HAZARDOUS MATERIALS
If hazardous materials are used, users must take responsibility to observe proper safety precautions, completely purge the instrument when necessary and ensure the material used is compatible with materials in this product, including any sealing materials.

PURGE THE INSTRUMENT
After installing the unit or before removing it from a system, purge the unit completely with a clean dry gas to eliminate all traces of the previously used flow material.

USE PROPER PROCEDURES WHEN PURGING
Purge the instrument under a ventilation hood. Wear gloves for protection during this procedure.

DO NOT OPERATE IN AN EXPLOSIVE ENVIRONMENT
To avoid explosion, do not operate this product in an explosive environment unless it has been especially certified for such operation.

USE PROPER FITTINGS AND TIGHTENING PROCEDURES
All instrument fittings must be consistent with instrument specifications and compatible with the intended use of the instrument. Assemble and tighten fittings according to manufacturer's directions.

CHECK FOR LEAK-TIGHT FITTINGS
Carefully check all connections to ensure leak tight installation.

OPERATE AT SAFE INLET PRESSURES
Never operate at pressures higher than the maximum operating pressure (refer to the product specifications for the maximum pressure).

INSTALL A SUITABLE BURST DISK

When operating from a pressurized gas source that may exceed the cavity proof pressure, install a suitable burst disk to prevent system explosion should the system pressure rise. (Refer to the product specifications for the cavity proof pressure)

KEEP THE UNIT FREE OF CONTAMINATION

Do not allow contaminants to enter the unit before or during use. Contamination such as dust, dirt, lint, glass chips and metal chips may permanently damage the unit or contaminate the process.

ALLOW PROPER WARM UP TIME

The unit may not meet all specifications unless sufficient time is allowed for the unit to stabilize at the designed operating temperature. Do not REL or calibrate the unit until the warmup is complete.

GROUNDING

Proper operation of this instrument requires that it be connected to earth ground. If the power source does not provide the required grounding, you should add a protective ground to the device."

COVERS

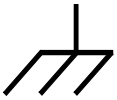
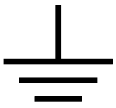
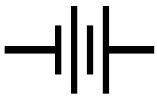
Do not operate the unit with the instrument covers removed.

RETURNS

All returns to SRS must be free of harmful, corrosive, radioactive or toxic materials.

Users returning a BGA244 back to the factory for repair and/or service must submit a correctly completed "Declaration of Contamination of Equipment" form, available as part of the RMA process. The SRS personnel carrying out repair and service of the BGA244 must be informed of the condition of the components prior to any work being performed. See *Appendix H* for information required on the "Declaration of Contamination of Equipment" form

Symbols You May Find on SRS Products

Symbol	Description
	Alternating Current
	Caution – risk of electrical shock
	Frame or Chassis terminal
	Caution – refer to accompanying document
	Earth (ground) terminal
	Battery
	Fuse
	Power On
	Power Off
	Power Standby

Specifications

Operational

Measurement Modes	Binary Gas Analyzer: Concentration in mole or mass fraction Gas Purity Analyzer: Deviation in speed of sound from ideal speed of sound / ideal speed of sound $\Delta W/W$ Physical Measurements: Measured Speed of Sound, Normalized Speed of Sound, temperature and pressure
Operating Pressure	0 to 150 psia (1000 kPa)
Operating Temperature	-20 °C to +70 °C
Flow Rate	0 to 5000 sccm
Gas Species	~500 gases supported in Factory Gas Table, Users can add gases to the User Gas Table
Response Time for a step change (2000 sccm flow rate)	9 seconds to 90% 18 seconds to 99%, 27 seconds to 99.9%
Minimum Detection Pressure	Gas Species Dependent (examples of pure gases) H_2 10 psia (69 kPa) He 10 psia (69 kPa) CH_4 4 psia (27 kPa) N_2 1 psia (7 kPa) Ar 1 psia (7 kPa) SF_6 1 psia (7 kPa)

Measurement

Measurement Technique	The Speed of Sound of the gas is measured using a cylindrical resonator using acoustic transducers. The gas temperature is measured using thermistors inside the resonant cavity. The Normalized Speed of Sound and Gas Concentration is calculated based on the cylindrical resonator characteristics and the thermodynamic properties of the gases.
Reading Rate	~4.4 Hz
Averaging	None, or 2 to 100 samples averaged
Temperature Measurement	Accuracy: ± 0.1 °C Resolution: 0.001 °C
Speed of Sound Measurement	Accuracy: ~0.02% Resolution: 10 ppm Stability: 10 ppm
Concentration[1]	Accuracy: typically 0.1% Resolution: 1 ppm Stability: 10 ppm

[1] All concentration specifications depend on the gas species being measured. See *Accuracy* in the *Application Guide* for more information.

Heater (opt 1)

Set Temperature	0 °C to 70 °C
Current Limit	0.05 to 2.5 A
Settling Time to final temperature	16 minutes for 25 °C to 50 °C temperature step, with 2 A max current
Protection	Over temperature and Over Current Protected

Analog I/O (opt 1)

Outputs

Function	Measure Out:	Gas Ratio, Gas Purity or Normalized Speed of Sound
	Output 1, 2:	Speed of Sound, Normalized Speed of Sound, Temperature, Pressure or User Value
Range	Voltage	0 to 5 V, 0 to 10 V
	Current	4 to 20 mA
Resolution	Voltage (5V range)	0.2 mV
	Voltage (10V range)	0.1 mV
	Current	0.5 µA
Accuracy[1]	Voltage[2]	±0.025 % + 1 mV
	Current	±0.1 % + 10 µA

[1] Output accuracy specifications are for User values. For Measure Out or Linked output values the accuracy is determined by the measured parameter being output.

[2] Voltage accuracy specifications apply for V > 0.4% of the Range

Max Output Current (Voltage Out)	20 mA
Max Load Resistor (Current Out)	840 Ω

Inputs

Function	Input 1, 2	Pressure Sensor or User Value
Range	Voltage	0 to 10 V,
	Current	4 to 20 mA, 4 to 20 mA with Loop Power
Loop Power Voltage	Range	6 to 19 V
	Resolution	0.1 V
Accuracy	Voltage	±0.025 % + 1 mV
	Current	±0.1 % + 10 µA
Input Impedance	Voltage	10 MΩ
	Current	201 Ω

Event Relay (opt 1)

Function	2 independently configurable DPDT relays that can be set to toggle on a combination of events
Events	Measurement limits, pressure limits, temperature limits, “No Signal” and System Fault
Relay Contact Rating	
Max Switching Power	30 W, 62.5 VA
Max Switching Voltage	220 V_{DC}, 250 V_{AC}
Max Switching Current	1 A
Max Carrying Current	2 A

Computer IO

RS-232

Format	No parity, 8 bits, 1 stop bit, CTS/RTS flow control
Baud Rate	2400 – 115.2k
Max Cable Length	>100 meters for lower baud rates

USB

Connector	USB Type B
Format	WHQL high speed USB2.0
Drivers available	Virtual COM Port (VCP) and Direct Drivers (USB drivers +DLL)
OS Support	
Microsoft	Windows7, 8 (32, 64 bit), Windows Vista, XP (32, 64 bit), Windows XP Embedded, Windows CE 4.2, 5.0 & 6.0
Other	Mac OS-X, Linux 2.6 & greater, Android

RS-422 (opt 1)

Format	4 wire, point-to-point, non-multidrop, no parity, 8 bits, 1 stop bit, no flow control
Baud Rate	2400 – 115.2k
Max Cable Length	>1000 meters for lower baud rates

Power

USB

Connector	USB Type B
Voltage	+5 V_{DC}, +/- 0.25 V *
Current	0.35 A (with display) 0.25 A (w/o display)

* The USB voltage must be >4.75V at the BGA244. Be sure to use a device that can supply enough current and a large enough wire gauge cable that can support this voltage. See *Power* in the *Installation Guide* for details.

Note that the USB current goes to 0 mA when +24V is connected.

+24 V (opt 1)

Connector	3.1 mm barrel jack, 2 wire terminal strip
Voltage	+24 V_{DC}, +/- 1 V
Ripple	<240 mV p-p
Current	
No Analog IO, Heater	0.2 A
Max	2.7 A

Environment

Cavity Proof Pressure	2500 psi (17 MPa)
Operating Temperature	-20°C to 70 °C
Storage Temperature	80 °C max
Humidity	<90 % relative humidity, non-condensing
Altitude	≤ 2000 m (for applications above this altitude, contact SRS)
Pollution Degree	Category 2: (EN61010-1; only non-conductive pollution)
Inbound Helium Leak Rate:	$1x10^{-8}$ sccs

Physical

Display Version	Color TFT-LCD w/ touchscreen Power, Communication and Error LED Indicators
Display-less Version	Power, Communication and Error LED Indicators
Dimensions	5.5” x 4.5” x 3.25” (WHL)
Weight	7 lbs (3.2 kg)
Swept Volume	130 cc (Acoustic Chamber Volume)
Gas Fittings Available	
Welded	¼” male VCR
Non-welded	¼”male VCR, ¼” female VCR, ¼” male VCO, ¼” compression fitting, ⅛”-27 female NPT, ¼”-18 female NPT, ¼” hose barb
Wetted Materials	Electro polished 304 stainless steel, gold flashed OFHC copper gaskets, nickel plated/immersion gold copper traces on 0.001” Kapton film, nickel plated NdFeB magnets, glass, constantan (Cu55/Ni45) wire and vented 316 stainless steel screws, nickel plated Dumet wire

Environmental Enclosure

When properly installed, the BGA244E (with Environmental Enclosure) will meet the following NEMA / UL-50 standards. See *Appendix x (Environmental Enclosure)* for installation instructions.

Rating	NEMA 6 (with catch latched) NEMA 6L (with screws installed) IP66, UL Type 4X, UL-50
Gas Fittings	⅛”-27 female NPT
Electrical	¾” Flexible, Non-Metallic Conduit (FNMC)

Pressure Transducer (opt T)

A Pressure Transducer can be ordered with the BGA244E. It must be ordered with the Industrial Control Option (Option 1).

Option BGA-T Specifications	
Pressure Range	0 – 150 psi absolute
Signal Output	4 – 20 mA
Loop Power	9 - 30 VDC
Accuracy	± 0.20%
Temp Coef	± 72 ppm / °C

Manual Convention

The BGA244 is operated thru a multilevel graphical user interface. The following conventions are used in the manual to describe different functions of the interface.

[Key]

This key is either a navigation key that will take you to a different display or a direct action key that will perform the action listed on the key.

[On|Off]

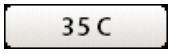
This is an on/off or enable/disable key. Pressing the key toggles the setting from one state to the other.

This indicates On or Enabled

This indicates Off or Disabled.

<Entry>

This indicates that a value needs to be entered where “Entry” is the name of the parameter. Pressing the key will open up the alpha-numeric keypad for data entry.



If the entered value is out of range, it will be ignored and an “Invalid Entry” prompt will appear indicating the maximum allowable value.

[ESC]

This key on the alpha-numeric keypad allows you to exit without entering a new value.

<Entry ↓>

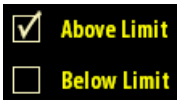
This indicates that a value needs to be selected from a list where “Entry ↓” is the name of the list. Pressing the key will open a drop list of possible selections. [Press] the desired selections to choose it. The current selection is normally highlighted in yellow.

◯ Choice

This indicates a “radio button” that is used to select one of a number of possible choices. Press the circle to select that choice and de-select all other choices.

☐ Choice

This indicates a check box that is used to enable a choice. Unlike Radio Buttons, you can select any or all of check boxes as needed.



(Home/Here/Over_There)

This denotes a location in the user interface hierarchy. To reach (Home/Here/Over_There) from the Home Page you would press [Here], followed by [Over_There].

[Home]

This returns you to the BGA244 Home Page. Note that the Home display has different appearances depending on the Analyzer Mode selected.

[←] or [Back]

This returns up one level from the display you are currently on.

[Help]

This takes you to the Help screen for that page. This page will have information about the settings and displayed parameters. [Page ↑] and [Page ↓] are active if the Help screen is more than one page long.

Note: The touch screen on the BGA244 must be actually be pressed to activate functions. This is normally indicated by a key click or beep. Hovering over the button like you do on a cell phone or tablet won't activate the control.

Throughout the manual, text in *Italics* refers to another section of the manual.

Unit Conventions and Abbreviations

Normal Temperature and Pressure (NTP)

Several different conventions are used to normalize measurements to a fixed temperature and pressure. The BGA244 uses "Normal Temperature and Pressure" (NTP) for all of its normalized readings. This is defined as the following:

- Temperature: 20.00°C, 293.15°K or 68.00°F
- Pressure (absolute): 1 atm, 101.325 kPa or 14.696 psia

Flow

There are a few abbreviations used to describe flow rate.

SCCM: standard cc (ml) per minute

SCCS: standard cc (ml) per second

Speed of Sound

The Speed of Sound is occasionally abbreviated as "SOS" in the manual.

Normalized Speed of Sound

The speed of sound in a gas varies as a function of several environmental parameters. The dominant effects are caused by pressure and temperature. An additional effect is caused by the frequency at which the speed of sound is measured. The frequency dependent effect is due to vibrational population relaxation effects in the gas molecules. This effect is specific to the particular gas being measured.

The BGA244 normalizes the speed of sound to NTP at the measured frequency.

The Normalized Speed of Sound is occasionally abbreviated as "NSOS" in the manual.

Pressure

Pressure can be referred to in either absolute or gauge pressure units. Absolute pressure units are relative to vacuum, while gauge pressure units are relative to the ambient pressure on the outside of the gauge.

When using gauge units it is important to enter the ambient pressure, as the BGA244 uses absolute pressure in its calculations.

How this Manual is Organized

This manual provides instructions on how to install and operate a BGA244 Binary Gas Analyzer.

Before installing your BGA244 in a system and/or operating it, carefully read and familiarize yourself with all precautionary notes in the Safety and Installation sections at the beginning of this manual. In addition, observe and obey all WARNING and CAUTION notes provided throughout the manual.

Chapter 1: Getting Started
Describes the BGA244 including measurements and applications and a quick start guide

Chapter 2: Installation Guide
Explains the environmental requirements and describes how to install the BGA244 in your system

Chapter 3: Operation Guide
Describes how to configure and operate the instrument and explains all of its functionality in detail

Chapter 4: Applications Guide
Describes how to optimize the BGA244 for the best performance in your application

Chapter 5: BGAMon
Describes how to configure and control the BGA244 using the BGAMon Windows software

Chapter 6: Remote Programming
Describes how to control the BGA244 using the computer interfaces

Chapter 7: Service
Troubleshooting, Maintenance and Calibration of the BGA244

Chapter 8: Theory of Operation
Theory of operation of the BGA244

Chapter 9: Circuit Description
Description of the BGA244s electronic circuitry

Appendix A: Gas Table
A list of all supported gases in the Factory Gas Table, plus a description of the data contained in the Gas Table

Appendix B: BGA244E
Description of the BGA244E, a NEMA enclosed version of the BGA244

Appendix C: Mechanical Drawings
Mechanical drawings and mounting locations for the BGA244 and its derivatives

Appendix D: Declaration of Contamination
Sample of the Declaration of Contamination form

Appendix E:
Instruction on manually installing the USB Drivers

Appendix F: Parts List
Parts list of the BGA244 and derivatives

Appendix G: Schematics
Electrical Schematics for the BGA244

Appendix H: Revisions
List of manual revisions

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Chapter 1: Getting Started

Binary Gas Analyzers

What is a Binary Gas Analyzer?

A Binary Gas Analyzer (or BGA) measures the ratio of two gases based on physical properties of the gases. Other instruments do this by measuring the thermal conductivity of the gas mixture or by measuring the speed of sound in the gas using a time-of-flight technique. Both the thermal conductivity and speed of sound of a gas vary inversely with their molecular weight (along with several other gas properties). So the ratio of two gases can be calculated if you know the properties of the two gases and the thermal conductivity or speed of sound in the mixture.

A different method of measuring the speed of sound uses a resonant acoustic cell. Measuring the resonant frequencies and knowledge of the cell's geometry allows the speed of sound to be accurately calculated. This information combined with knowledge of the physical properties of the gases allows you to accurately determine the ratio of the two gases.

The BGA244 works by injecting a wideband acoustic signal into a gas cell using a speaker. The resonant modes of the cell are excited, producing large amplitudes at the resonant frequencies. This signal is measured using a sensitive, wideband microphone. Advanced signal processing extracts the frequencies of the resonant peaks and from them, the speed of sound.

Combining the speed of sound, temperature and pressure with a detailed list of about 500 different gases allow the BGA244 to make ratio measurements with a typical accuracy of better than 0.1%

This technique isn't just reserved for gases of a single species. Blended gases can also be measured, as long as physical data is available for each gas blend. The best known blended gas is air, made up of nitrogen, oxygen, argon and carbon dioxide. There are many other blended gases that can be used in the BGA244.

Most binary gas analyzers are factory configured to support a handful of gases, or only a single mixture and limited range. In contrast, the BGA244 comes configured with data on nearly 500 gases with a wide range of concentrations. This gas information is easily selected from the front panel or can be configured remotely, allowing over 50,000 mixtures to be measured.

In addition to binary gas ratio measurements, the BGA244 can report purity of a gas expressed as the ratio of the measured speed of sound to the expected speed of sound. To support other research goals, measurements of the speed of sound, temperature and pressure can be reported directly.

Uses for Binary Gas Analyzers

Binary gas analyzers are used in a wide range of applications. They are often used in applications where no dedicated sensors exist for a gas or for indirectly controlled mixtures in a process.

A few typical applications are:

- Leak Detection
- Semiconductor Processing
- Food Processing
- Quality Control
- Environmental Monitoring
- Purge Gas Analysis
- Shielding or Blanketing Gas Monitoring
- Generator Cooling Gas Monitoring
- Heat Treating Gas Monitoring
- Gas purity monitoring
- Measuring Helium – Deuterium ratio
- Measuring He-3 / He-4 ratio

Features and Accessories

The BGA244 consists of a compact package which includes the resonant cell, acoustic transducers, sensitive electronics and advanced signal processing. It can be powered over USB or +24 V and can interface to external devices by computer interface or analog signals and features a touch screen LCD to configure and monitor measurements.

There are two models in the BGA244 series: the standard BGA244 and the BGA244E (enclosure). Both models share the same acoustic resonant cell, transducers, signal processing and basic computer interfaces. The standard BGA244 is available with several options. See *Appendix B* for information about the BGA244E.

Gas Fittings

The BGA244 is ordered with one of the following gas fittings.

TABLE 1: GAS FITTING OPTIONS

Option	BGA244 Gas Fitting
A	¼" Male VCR
B	¼" Female VCR
C	¼"Male VCO Body
D	¼" Compression Fitting
E	⅛" -27 Female NTP
F	¼" -18 Female NTP
G	¼" Hose Barb (¼" ID hose)
H	¼" Welded Male VCR

Electrical Connections

All versions of the BGA244 can be powered via their USB connector. This can be connected to a computer, a powered USB hub or a USB charger. Instrument functions can be controlled over either the USB or RS-232 computer interfaces. See *Figures 1 & 2* (page 6) for the connector locations.

There are three LEDs that indicate the status of the BGA244.

Name	Function
Power (green)	Shows that power is applied Flashes for power fault codes
Comm (green) (Communication)	Flashes when computer interface is active
Error (red)	Flashes for communication error Repetitive blink for various no signal errors. Constant on for "System Fault"

Industrial Control Option (Option 1)

The Industrial Control Option (Option 1) adds the following features to the basic BGA244. (See *Figure 2*, page 6)

- +24V power input
- RS-422 computer interface
- Analog I/O (3 outputs & 2 inputs)
- 2 configurable Event relays

Standard and No Display Option (Option 2)

The standard BGA244 includes a color TFT-LCD w/ touchscreen. This can be used to configure the unit and display results. The unit can also be configured using the computer interfaces. (See *Figure 3,* page 7)

The No Display Option (Option 2) replaces the display with a rugged solid cover. Units with Option 2 can only be configured over the computer interfaces using the BGAMon program or user written code. (See *Figure 4,* page 7)

Accessories

There are several different accessories available for the BGA244.

USB Power Supply (BGA-5)

Accessory BGA-5 is a 5 watt USB power adapter. The appropriate adapter will be shipped, based on the country being shipped to (North America, Europe, UK and Australia/New Zealand).

Be sure to use an appropriate USB cable when powering the BGA244 over USB. The cable that is included with the BGA244 is suitable. See *Power in the Installation Guide* for information on suitable USB cables.

+24V Power Supply (BGA-24)

Accessory BGA-24 is a 50W universal input power supply that provides +24 V at 2.5 A. Note that this accessory requires the Industrial Control Option (Option 1) be installed.

Shield (BGA-S)

Accessory BGA-S is an Acrylic shield used to protect the BGA244 Display. This accessory is not needed for units without displays (Option 2).

Note that the display touch screen will not operate through the Acrylic shield. It is necessary to first remove the shield before using the touch screen. Replace the Acrylic shield when you are done using the touch screen.

BGA244E

The standard BGA244 is designed for use in a relatively clean environment. The BGA244E packages the standard BGA244 in a NEMA Type 6/6P enclosure for use in exposed locations. See *Appendix B* for information on the BGA244E. All options and accessories except the gas fittings (Options A – H) are available on the BGA244E.

Pressure Transducer (Option T)

Option T is a 0 – 150 psia pressure transducer that can be ordered with the BGA244E. It comes installed inside of the enclosure. Note that this accessory is only available on units with the Industrial Control Option (Option 1).

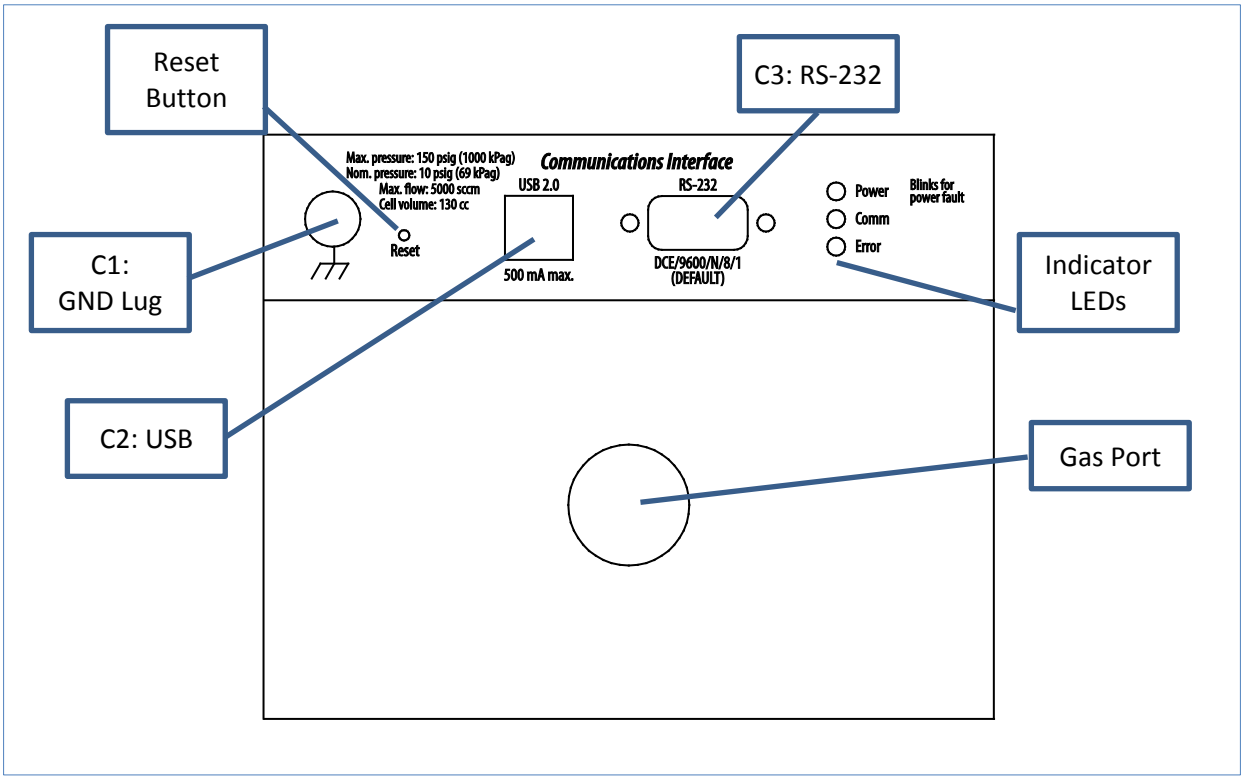


FIGURE 1: BGA244 PLAIN (NON OPTION 1)

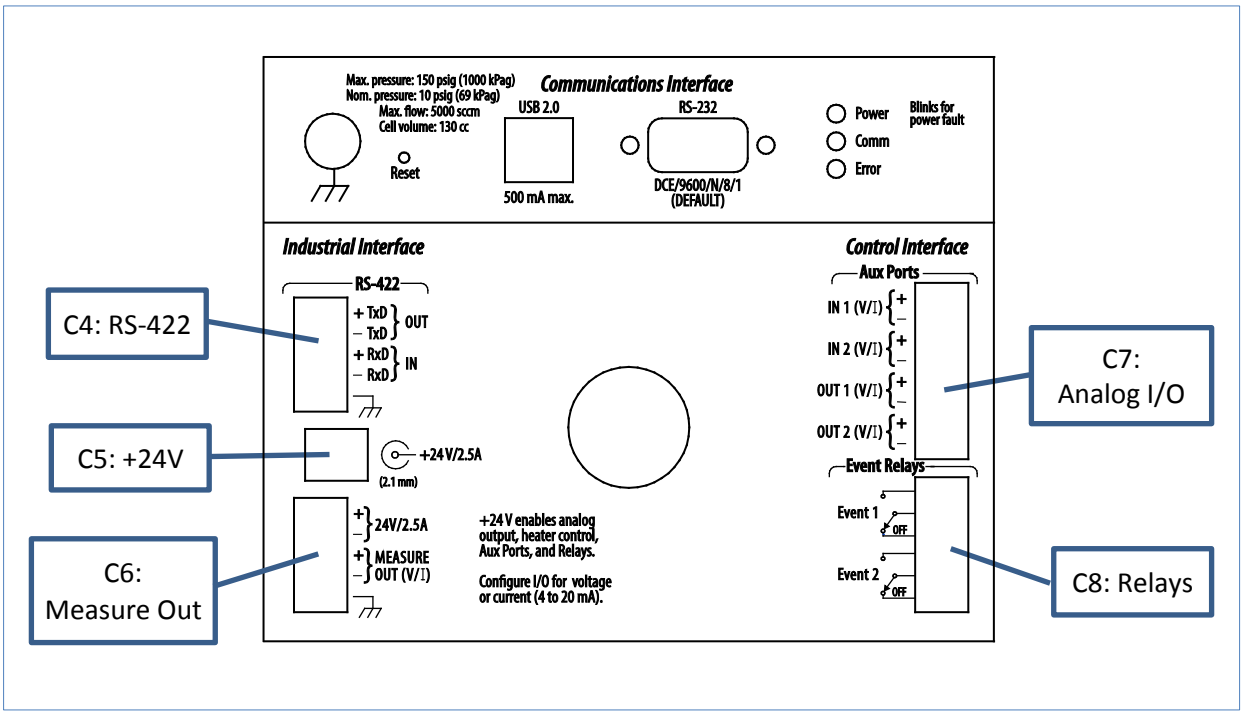


FIGURE 2: BGA244 (OPTION 1)

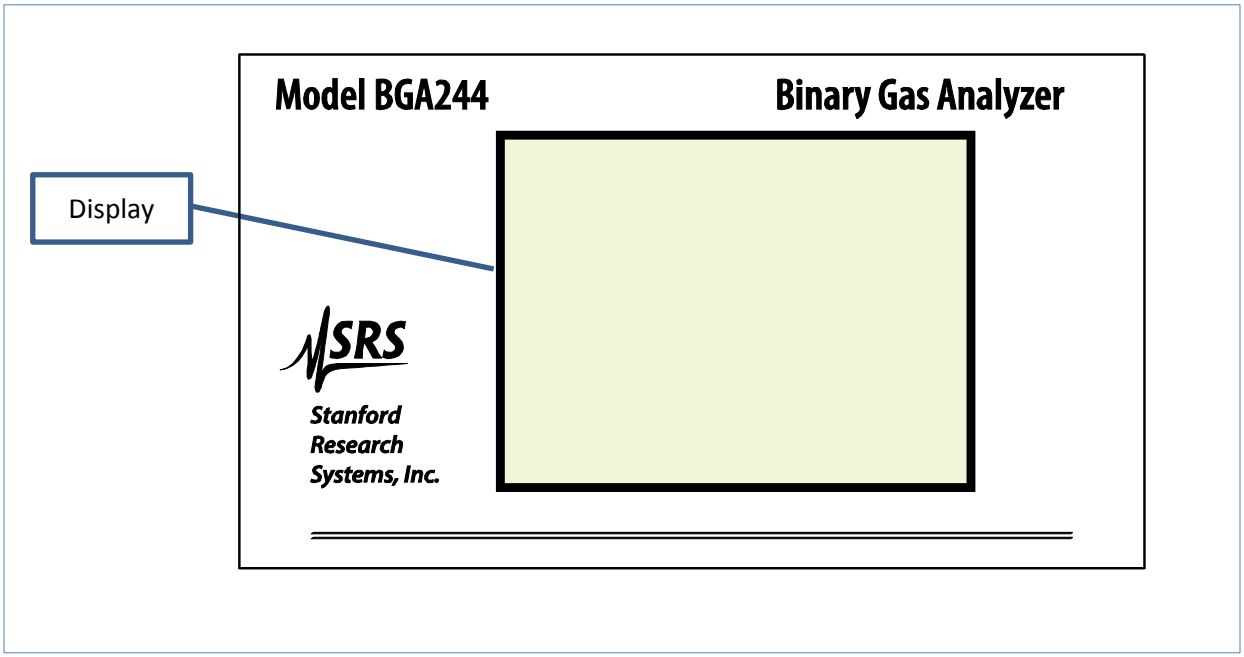


FIGURE 3: BGA244 WITH DISPLAY (NON-OPTION 2)

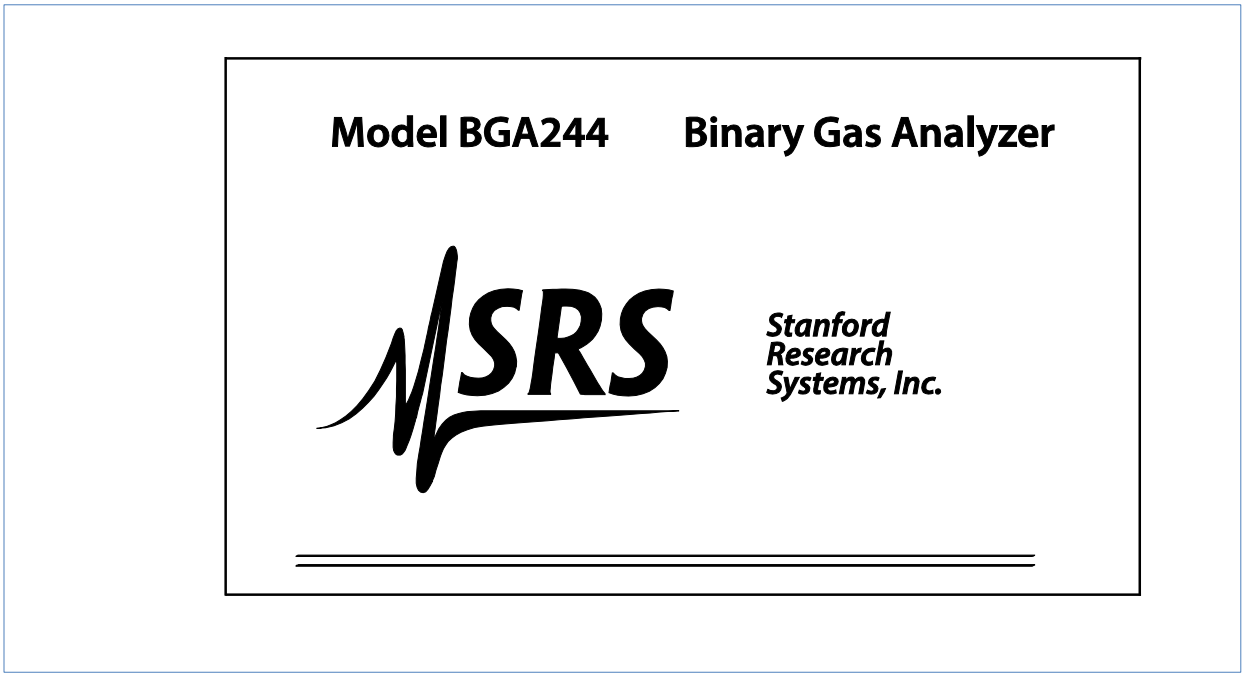


FIGURE 4: BGA244 WITHOUT DISPLAY (OPTION 2)

Unpacking

Before You Open the Box

Do not remove the gas port dust caps until just prior to connecting the unit to your gas manifold to reduce the chance of contamination of the cell.

Read the *Chapter 2: Installation Guide* prior to installing the BGA244 into your system.

Read the *Chapter 3: Operations Guide* and *Chapter 4: Applications Guide* prior to operating the BGA244.

Inspect all components of the SRS BGA244 upon unpacking. Report any damage to Stanford Research Systems immediately. Compare the contents of the shipping container to the list below and report any discrepancies.

See *Appendix B* for information specific to the BGA244E.

What is included

Standard BGA244

1. One BGA244 w/ selected Gas Fittings (Option A – H)
2. One 6’ (1.8 m) USB cable
3. One Operation and Service Manual

Options

1. Option 1 Industrial Control Option (installed at Factory)
2. Option 2 No Display Option (installed at Factory)

Accessories

1. BGA-5 USB Power Supply
2. BGA-24 +24V Power Supply
3. BGA-S Acrylic shield for the LCD display

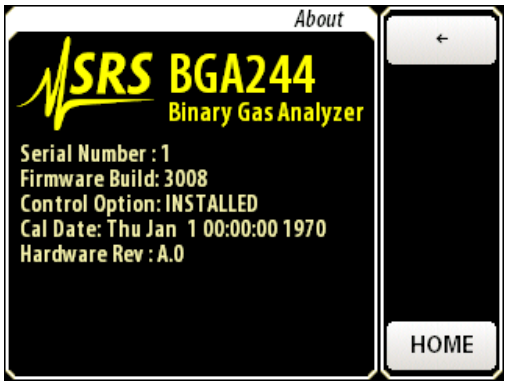
Quick Start

This guide is intended to help users get started making measurements with the BGA244. These instructions are designed for units with displays (non-Option 2). For units without displays (Option 2) it is recommended to use the BGAMon software to configure the unit and monitor the results. Refer to *Chapter 5: BGAMon* for details.

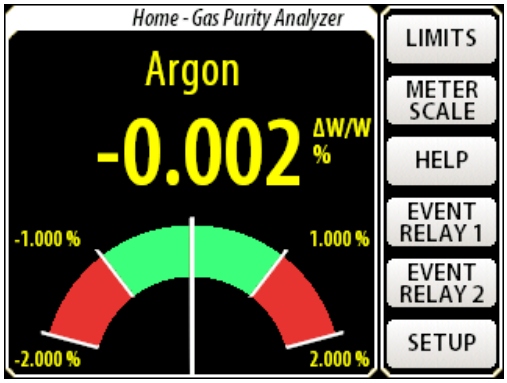
Quick Test

Connect power using either USB power or +24V (Option 1 required). If using USB power make certain that the USB device and cable are sufficient to power the device. See *Power* (page 21) for more information.

When power is first applied, a power-on splash screen will appear. After a few seconds the "About" information page which displays the unit serial number, firmware version, installed options, calibration date and hardware version.



After about 15 seconds the Gas Purity Analyzer Home page will appear. Assuming the unit has come from the factory and the dust caps haven't been removed, it should display close to 0% deviation from Argon.



Disconnect power before continuing with the following steps.

Installation and Configuration

Plan your installation, including mounting and gas tubing connections. Depending on your application, this can be as simple as setting the BGA244 on a bench and connecting flexible tubing or may involve hard mounting the unit and forming metal tubing. Be sure to clean out gas lines prior to connecting them to the BGA244 to avoid contamination. Refer to *Chapter 2: Installation Guide* if you have any questions regarding these procedures as improper installation can damage the unit.

1. Mount the BGA244 as appropriate to your application.

2. Connect the gas tubing to the gas ports following the appropriate procedure for the gas fittings.

3. Connect either USB power or +24V (Option 1 required). If using USB power, be certain that the USB device and cable are sufficient to power the device. Refer to *Power* (page 21) for more information. The splash screen and "About" page should appear as described in Quick Test.

4. Configure the BGA244. Note that it may be easier to configure the unit prior to installing it into your system, especially if access is restricted. See *Chapter 3: Operation Guide* for more information on each of the following steps.

    a. Set the Instrument Mode: [HOME] [SETUP] [INSTRUMENT MODE ↓]. There are 3 choices: Binary Gas Analyzer, Gas Purity Analyzer or Physical Measurements.

    b. Select the Gas(es): [HOME] [SETUP] [SELECT GAS]. Set Gas 1 and Gas 2 for Binary Gas Analyzer mode or set a single Gas for Gas Purity and Physical Measurements modes. Press [SELECT GAS] to open the gas selection window. Type the first few characters of its name, formula or CAS number, then press [ENTER] to open a list of gases that match that string. Select the desired gas from that list.

    c. Configure the Pressure: [HOME] [SETUP] [PRESSURE]. Press [ENTER USER PRESSURE] to open the User pressure window. This is simplest way to enter the pressure.

    d. Set the Meter Scale and Limits: [HOME] [METER SCALE] and [HOME] [LIMITS] appropriately. (Binary Gas and Gas Purity Analyzers only).

5. Flow gas through the system. The BGA244 should display the selected gases and concentration, purity or physical measurements of the gas.

Windows Drivers for the BGA244

If the BGA244 is connected to the USB port of a computer running Microsoft Windows, you may be prompted with a "New Hardware Found" message and an invitation to search for the USB Driver. There are two USB drivers for the device (VCP and D2XX drivers). Depending on the version and configuration, Windows may either automatically install the drivers or prompt you to search for them. Allow it to install the drivers if you plan to configure or control the BGA244 using this computer. If there are difficulties installing the driver, see *Appendix E* for details on manually installing the drivers. If you have no plans of using this computer to configure or control the BGA244, cancel the driver installation.

Units without Displays (Option 2)

The simplest way to verify the operation of a BGA244 without a display (Option 2) is using the BGAMon software. This software runs on a Windows compatible computer and communicates with the BGA244 over USB. See *Chapter 5: BGAMon* for details.

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Chapter 2: Installation Guide

The BGA244 can be installed in a variety of ways to interface with gas systems. For bench top experiments, it can operate freestanding on its non-slip feet. For more robust installations it can be bolted to a mechanical plate in any orientation. There is no preferred direction of gas flow. The LCD display can be rotated to any orientation for convenient viewing.

There is a wide range of different gas fittings available to easily connect to different systems. Units can be power over the USB interface or by +24 V_{DC}. The BGA244 can be easily connected to an automated system over any of its three computer interfaces. In addition, there are configurable event relays and connections for analog input and output signals.

The standard BGA244 is designed to be operated in a clean and dry environment. The BGA244E is recommended for locations that may be exposed to wet or dirty conditions. The BGA244E packages the standard BGA244 in a NEMA Type 6/6P enclosure for use in exposed locations. See *Appendix B* for information on the BGA244E.

Operating Environment

Temperature

The operating temperature range of the BGA244 is from -20° to 70 °C. Do not expose the BGA244 to bake out temperatures above 80 °C.

If the BGA244 is being operated at an ambient temperature below -20 °C use the heaters to raise the operating temperature. It may be necessary to insulate the unit to bring the temperature within the operating range.

Pressure

The BGA244 can make reliable measurements with pressures ranging from around 5 psia (34 kPa) to as high as 150 psi (1000 kPa) depending on the gas species. The design proof pressure is 2500 psi (17.2 MPa) making secondary containment chambers unnecessary. The nominal operating pressure is 10 psig (69 kPag).

Flow

The BGA244 is specified for flow rates from 0 to 5000 sccm. Customers have successfully operated at flow rates as high as 20,000 sccm.

Gas

Gases must be clean and dry (free of any solid or liquid particulates). In addition they must be non-condensing at the operating temperature and pressure. See Gases (page 91) for more details.

Electrical and Magnetic Fields

Strong electrical or magnetic fields can interfere with the BGA244. These can make measurements noisy or even impossible to make. The best solution is to make sure that the BGA244 is separated from interfering sources. If this isn't possible, see Interference (page 101) for suggestions on shielding techniques.

Avoid passing currents through the BGA244 from the gas lines. This can generate interfering signals. Make sure that all pipes are properly grounded.

Access

Front Panel

As the BGA244 can be operated or viewed from the front panel, it is necessary to have a clear view and easy access to the LCD and touch screen. This is less important if operating over a computer interface, although it is useful to have access to the front panel for debugging purposes.

Visibility of the status LEDs is helpful, especially for units without displays (Option 2).

Wrench Clearance

Most of the gas fittings that connect to the BGA244 require one or more wrenches to fully tighten. Make sure there is sufficient clearance, both in length and rotation. See the Swagelok Installation guidelines for the different gas fittings for details.

Cable Clearance

Typical USB and RS-232 and RS-244 cables require about 2.5" (65 mm) clearance from the BGA244. The +24 V barrel connector (Option 1 with BGA-24) and terminal strips (analog I/O and relay connections) need about 2.0" (50 mm) of clearance.

Ventilation Clearance

When the heaters are not operating, the BGA244 dissipates between 2 to 5 watts, depending on the operating condition. Therefore, ventilation clearance isn't required. When operating, the heaters adjust their power to maintain a constant temperature. This eliminates the need for any additional ventilation.

Service Access

Besides the terminal block connectors and the gas fittings there are no user serviceable parts in the BGA244. *Chapter 7: Service* for details on servicing the unit.

Installation

Plan the location of the BGA244, gas pipes, fittings and electrical connectors prior to mounting the unit and forming tubing. Take into account cable routing to minimize electrical interference. Refer to *Electrical Connections* (page 18) for more details. The BGA244 can be mounted in any orientation. There is no preferred gas flow direction; either gas port can be input or output. See Figure C-1 in *Appendix C* for the location of the gas ports, electrical connectors and mounting points.

Clean out the gas lines before connecting the BGA244 to remove any particulates or oils. These can contaminate or damage the acoustic cell.

Strong mechanical vibrations may interfere with obtaining accurate measurements. Whenever possible mount the BGA244 in a location that is free of large vibrations or impacts.

Do not rely on the inlet and outlet tubing to support the weight of the BGA244 to avoid damaging either the tubing or the unit. Either mount the BGA244 to a rigid plate or rest it on its non-stick feet.

The distance between the two gas fittings depends on selected gas fitting options. The spacing between outside of each fitting is given by dimension “X” in the Gas Fitting Table. Remember to take into account any gaskets (VCR or VCO), ferrules or thread insertion when determining pipe length. Refer to *Gas Fittings* (page 16) for more details.

The BGA244 is mounted using four 10-32 screws. The maximum penetration depth of the screws is 0.38” (9.6 mm). Either remove the rubber feet or relieve the area beneath them for hard mounting to a rigid plate. This helps to avoid vibration problems. The use of stainless steel mounting screws is not recommended. However if it is required, use lubricant to prevent galling.

Procedure

- Fasten the BGA244 to the mounting surface as described in the previous section. If rigid preformed tubing is used, it may be necessary to remove the caps from the gas fittings before mounting.
- Connect the gas lines as described in *Gas Fittings* (page 16), following the Swagelok Installation guidelines. See the Swagelok Installation guidelines for any washers or O-rings that may be required.
- Connect the electrical cabling for power, analog and computer I/O as described in *Electrical Connections* (page 18).

Gas Fittings

The BGA244 is available with a number of different gas fitting options that are listed in the following table. Each BGA244 has two identical gas fittings. All of the fittings are Swagelok products whose part numbers are included for reference. Dimension "X" refers to the outside dimension of the gas fittings as shown on Figure C-1 in *Appendix C.* Refer to the specific fitting guidelines for more details.

TABLE 2: GAS FITTING DIMENSIONS

Option	BGA244 Gas Fitting	Part Number	Dimension X
A	¼" Male VCR	SS-4-VCR-1-2	4.780"
B	¼" Female VCR	SS-4-WVCR-1-2	5.320"
C	¼"Male VCO Body	SS-4-VCO-1-2	4.455"
D	¼" Compression Fitting	SS-400-1-2	4.715"
E	⅛" -27 Female NPT	SS-2-A	4.360"
F	¼" -18 Female NPT	SS-4-RA-2	4.680"
G	¼" Hose Barb (¼" ID hose)	SS-4-HC-1-2	5.100"
H	¼" Welded Male VCR	SS-4-VCR3-4MTW + SS-4-VCR-4	4.770"
	VCR Gasket	SS-4-VCR-2	0.028"

Welded Fittings

Option H uses welded, non-replaceable Male VCR fittings, intended for high purity systems. These fittings are assembled without any pipe thread sealant or tape. If these fittings are damaged, the unit needs to be returned to SRS for repair.

Follow the Swagelok VCR Fitting Installation Instructions when connecting to the BGA244. Remember to install a new VCR gasket between male and female fittings. Use 2 wrenches to tighten the fittings so as to not damage the unit. Swagelok recommends tightening VCR fittings ⅛ turn past finger tight for stainless steel or nickel gaskets.

Non-welded Fittings

The remaining fitting options are non-welded. These can be replaced in the field if damaged. The body of the BGA244 is machined with two gas ports each with ⅛"-27 FNPT threads. The fitting adapters are fastened to these ports. If damaged, the adapters can be replaced by the customer. See the *Chapter 7: Service* for details on the proper procedure to replace the gas fittings. It is not recommended that NPT pipes are directly connected to the BGA244. Instead use NPT thread adapters to avoid damaging the port threads.

The fitting adapters are installed using Loctite 565 thread sealant. This helps to seal leaks and prevent galling/seizing of the threads. Allow Loctite 565 at least 24 hours to cure before applying pressure or vacuum to the system.

Options A and B are replaceable VCR fittings, similar to option H. Follow the Swagelok VCR Fitting Installation Instructions when connecting to the BGA244. Remember to install a new VCR gasket between male and female fittings. Use 2 wrenches to tighten the fittings so as to not damage the unit. Swagelok recommends tightening VCR fittings ⅛ turn past finger tight for stainless steel or nickel gaskets.

Option C is a VCO fitting. Follow the Swagelok VCO Fitting Installation Instructions when connecting to the BGA244. Use 2 wrenches to tighten the fittings so as to not damage the unit. Swagelok recommends tightening VCO fittings ⅛ turn past finger tight.

Option D is an adapter for a ¼" tube fitting. Follow the Swagelok Gaugeable Tube Fittings and Adapter Fittings Installation Instructions when connecting to the BGA244. Use 2 wrenches to tighten the fittings so as to not damage the unit. Do not over tighten these fittings.

Options E and F are female NPT adapters for ⅛" and ¼" pipes. Follow the Swagelok Pipe Fitting Installation Instructions when connecting to the BGA244. Swagelok recommends using a pipe thread sealant when assembling tapered threads.

Options G is a ¼" ID hose end connections for soft tubing and hose. Follow the Swagelok Hose and Flexible Installation Instructions when connecting to the BGA244.

Electrical Connections

Be sure that your installation confirms to all safety and electrical code requirements.

For CE compliance it is recommended that all power and I/O cables are shielded and grounded.

The BGA244 has no line voltages connections. Applying line voltage to any pin of any connector on the BGA244 will cause severe damage to the instrument and is a fire and smoke hazard.

The BGA244 supports a wide variety of electrical connections for power, control and monitoring. Power is provided over USB (+5V_{DC}) or a separate +24 V_{DC} power supply. Computer interfaces include USB, RS-232 and RS-422. There are multiple user configurable analog inputs, analog outputs and two configurable event relays.

Electrical Noise Precautions

Electrical Noise can cause interference between different devices. AC line wiring, motors, pumps, relays and their control wiring are common noise sources. Wherever possible, route the BGA244 wiring separate from noise sources. This is a particular concern for the Analog I/O signals.

There are two main groups of connections used by the BGA244. Wires within each group can normally be bundled together without adverse effects. Try to avoid combining wires from different groups, especially for long cable runs.

Group 1:	Power, ground, computer interfaces and relay signals
Group 2:	Analog Inputs, Analog Outputs

Avoid passing current through the BGA244 and its gas tubing. This can be accomplished by providing a current return path for high current wiring and making sure that all metal surfaces are properly grounded.

Grounding

Make sure that the BGA244 is properly grounded. Depending on the installation, power supply wiring and gas tubing may not be properly connected to earth ground. If necessary, connect the BGA244 chassis ground lug (C1) to a suitable earth ground.

Electrical Connectors

Basic BGA244

A BGA244 without Option 1 is powered over the USB connector. This can be connected to a computer, a powered USB hub or a USB charger. In addition a RS-232 DCE port is provided, as well as a ground lug. See Figure 1 for the connector locations (page 6).

- Ground Lug (C1)
- USB for Power and Computer Control (C2)
- RS-232 Interface for Computer Control (C3)

Option 1 (Industrial Control Interface)

Option 1 adds the following power supply and electrical I/O features to the basic BGA244. It also adds internal heaters used to bake out the unit and stabilize the internal temperature. See Figures 1 and 2 for the connector locations (page 6).

- RS-422 Interface for Computer Control (C4)
- +24V Power Connector (C5)
- Analog Measure Out and +24V Power (C6)
- 2 Analog Outputs (0-5 V, 0-10 V, 4-20 mA) (C7)
- 2 Analog Inputs (0-10 V, 4-20 mA, 4-20 mA w/ loop power) (C7)
- 2 Event Relay Contacts (C8)

Connector Pinouts

TABLE 3: C3: RS-232

Pin	Signal
1	CD
2	Rx
3	Tx
4	DTR
5	GND
6	DSR
7	RTS
8	CTS
9	RI

TABLE 4: C4: RS-422

Pin	Signal
1	Chassis GND
2	-RxD
3	+RxD
4	-TxD
5	+TxD

TABLE 5: C5: +24V

Pin	Signal
1 (Center)	+24 V_{DC}
2 (Outside)	GND (24V Return)

TABLE 6: C6: MEASURE OUT

Pin	Signal
1	Chassis GND
2	GND (Measure Return)
3	Measure Out
4	GND (24 V Return)
5	+24V

TABLE 7: C7: ANALOG I/O

Pin	Signal
1	Analog In 1 +
2	Analog In 1 -
3	Analog In 2 +
4	Analog In 2 -
5	Analog Out 1 +
6	GND (Out 1 Return)
7	Analog Out 2 +
8	GND (Out 2 Return)

TABLE 8: C8: RELAY CONTACTS

Pin	Signal
1	Relay 1 Normally Open
2	Relay 1 Common
3	Relay 1 Normally Closed
4	Relay 2 Normally Open
5	Relay 2 Common
6	Relay 2 Normally Closed

Terminal Strip Connectors

The BGA244 uses Phoenix Contact Combicon MC Series connectors for its terminal strips. Each terminal strip is made up of two pieces: a PCB soldered base strip and a detachable terminal block. Each terminal strip connector in the BGA244 comes with its terminal block inserted into the base strip.

> **Tip:** It's usually easier to remove the terminal strip from the BGA244 before connecting wires. Unplug the terminal strip by pulling straight back from the unit. Loosen the screws before inserting the wires. Make sure to observe the correct pinouts!

The terminal blocks can accept wire sizes from 16 – 28 AWG (1.29 – 0.32 mm dia). Wires are secured by screw connection. Wires may be attached to the terminal block when it is disconnected from the base strip to simplify assembly. Make sure the wire installation is stripped back far enough to ensure good electrical contact.

Be sure to use the correct pinout for each connector. Failure to do so can result in damage to the BGA244. Pay special attention to C4 and C6, as they are adjacent and have the same number of pins. Replacement terminal blocks are available from Digikey or other distributors.

Connector	Phoenix Contact p/n	Digikey p/n
C4, C6 (5 pin)	1803604	277-1164-ND
C7 (8 pin)	1803633	277-1167-ND
C8 (6 pin)	1803617	277-1165-ND

Power

USB Power

A BGA244 without Option 1 must be powered through its USB Type B connector (C2). If Option 1 is installed, the unit can operate over either +24V or USB power. (Remember that most of the Option 1 features require +24V to operate).

It's frequently convenient to configure units at a desktop computer using USB power (even units with Option 1). All parameters can be configured under USB power, but features that depend on +24V won't operate until +24V is supplied.

When running, the BGA244 draws about 0.35 amps from the USB interface. It requires the USB voltage to be within 4.75 to 5.25 V_{DC}. If the voltage is outside this range, an Alert is displayed. If the voltage drops below 4.6 V_{DC} a Fault is generated and the unit will not operate. Refer to *Faults* (page 82) for more details.

Most USB chargers, desktop and laptop computers can supply the proper voltage and current. A dedicated USB charging port or charging downstream port is specified to supply enough current to operate the BGA244. A plain downstream port can probably supply enough current.

The USB voltage will droop below the acceptable range if a device cannot supply enough current. Add a powered hub to increase the voltage and current. Make sure that the powered hub is capable of providing around 0.5 amps to a single port.

USB Power Cables

All USB cables are not created equal!
Some USB cables have power wires as thin as 24 AWG. These produce large voltage drops that cause the BGA244 voltage to drop below its operating range. Thin USB cables typically have small gauge power wires.

Use USB cables that have 20 AWG power wires. The power wire gauge is frequently printed on the cable or packaging. SRS recommends Belkin Gold Series Hi-Speed USB 2.0 cables. These are available from Amazon, CDW and other distributors.

Length	Belkin p/n
6’ (1.8M)	F3U133-06-GLD
10’ (3.0M)	F3U133-10-GLD

BGA-5 USB Power Supply

Accessory BGA-5 is a 5V, 1A USB power supply suitable to power the BGA244.

+24V Power

If the Industrial Control Interface (Option 1) is installed, the BGA244 can be powered by +24 V_{DC}. If the USB port is connected to an external device, its current goes to 0 A when the BGA244 is powered by +24 V.

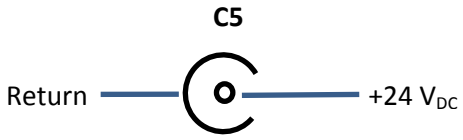
The acceptable voltage range is 24, ±1 V_{DC}. The maximum ripple voltage is < 240 mV_{PP}. The maximum +24 V power supply current is 2.7 A. However the BGA244 can be operated at much lower currents. With the heaters turned off, the +24 current draw is between 0.2 – 0.35 A, depending on the analog I/O configuration. The maximum heater current can be set to anywhere from 0.01 to 2.2 A.

Conditions	Current
No Heaters, No Analog IO	0.2 A
Using Analog IO	Add 0.15 A
Using Heaters	Add Max Heater Current setting (0.01 – 2.2 A)

Make sure that the wire gauge used to connect the +24 V power supply can support the maximum current required without excessive voltage drops. If operating at the maximum heater current, 100 feet (30 meters) of 18 AWG wire will have a voltage drop of ~3.5 V_{DC}. Lower currents and shorter wires will minimize this drop.

There are two different connectors that can be used to provide +24 V power. Power can be provided using connector C5, a 3.1 mm barrel jack (see figure) or on pins 4 and 5 of terminal strip C6. Make sure to connect the +24 V power supply with the correct polarity, to the correct pins. Failure to do so may cause serious damage to the BGA244.

C6	
C6 pin 5	+24 V_{DC}
C6 pin 4	Return



BGA-24 USB Power Supply

Accessory BGA-24 is a 100 – 240 V_{AC} input, 24V, 2.5 A output power supply suitable to power the BGA244 with Option1. It connects to the BGA244 using the 3.1 mm barrel jack (C5).

Computer Interfaces

The BGA244 can be remotely operated over the USB interface, the RS-232 serial interface, or the optional RS-422 serial interface. Any host computer interfaced to the instrument can control and monitor all of its functions. For details on configuring and monitoring the interfaces, see *Computer I/O* (page 76). All interfaces communicate with the BGA244 using the commands listed in *Chapter 6: Remote Programming.*

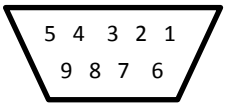
USB

The USB type B connector (C2) is located on the front of the BGA244. The interface is USB 2.0, Full Speed compatible. USB 2.0 is specified for a maximum cable length of 5 meters. If powering the BGA244 over USB, be sure cable is able to support the operating current. See *USB Power Cables* in the previous section for details. Before a computer can control the BGA244 over USB, it needs to have the appropriate USB driver installed. Refer to *Using the USB Drivers* (page 172) for details on installing and using the USB drivers.

If you connect the BGA244 using a computer running Microsoft Windows, it may detect the USB Interface Chip and offer to install two drivers for the device (VCP and D2XX drivers). Depending on the version and configuration, Windows may either automatically install the drivers or prompt you to search for them. If you need to search for them, the drivers are located at the FTDI web site: www.ftdichip.com/Drivers. If there are difficulties installing the driver, refer to *Appendix E* for details on manually installing the drivers.

RS-232

RS-232 connector C3 is located on the front of the BGA244. The connector is a standard 9 pin, type D, female connector configured as a DCE (transmit on pin 2, receive on pin 3). CTS and RTS are supported. See figure for the connector pin numbering.



RS-232 PINOUT

In order to communicate properly over RS-232, both the BGA244 and the host computer must be set to the same configuration. The RS-232 interface supports baud rates from 2400 to 115.2 k baud. In general, the highest baud rates will operate successfully for shorter cable lengths. At lower baud rates, cable lengths over 100m (300 ft) should be possible. Communication errors can be caused by excessive cable length, overly high baud rates or electrical noise. If errors occur, operating at a lower baud rate will usually help.

RS-422

The RS-422 connector (C4) is part of Option 1 (Industrial Control Option) and can only be used if an external +24 VDC power supply is connected to the BGA244. Connections to the RS-422 interface are made using terminal block C4 located on the front of the BGA244.

The RS-422 interface is implemented as a 4 wire, point-to-point, non-multidrop connection. It supports a single transmitter and single receiver pair. Connections are made using a 5 pin terminal strip. Tx and Rx connections between the BGA244 and host should be made as follows. Note that the transmit pins on the BGA244 connect to the receive pins on the host and the receive pins of the BGA244 connect to the transmit pins of the host.

BGA244 pin number	BGA244 Connection	Host Connection
C4-5	+TxD	+RxD
C4-4	-TxD	-RxD
C4-3	+RxD	+TxD
C4-2	-RxD	-TxD
C4-1	GND	GND

RS-422 PINOUT

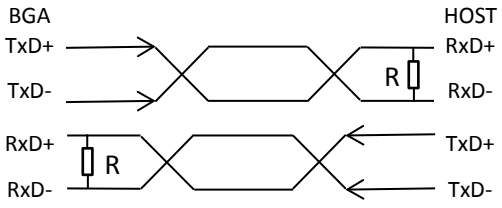


FIGURE 5: RS-422 SIGNAL PATH

Use twisted pair cabling with an impedance of ~100 Ω, especially for longer cable runs and higher data rates. Shielded Cat5 or Cat6 cable is a good choice. A 100 Ω terminating resistor (R) can be added to each receive end for long cable runs or high data rates to improve signal quality. The resistor should be rated for at least ¼ watts. The resistor can be connected along with the RxD lines at the BGA244 terminal strip.

In order to communicate properly over RS-422, both the BGA244 and the host computer must be set to the same configuration. The RS-422 interface supports baud rates from 2400 to 115.2 k baud. RS-422 can operate at cable lengths over 1000 m (3250 ft). In general, the highest baud rates will operate successfully for shorter cable lengths. Communication errors can be caused by excessive cable length, missing terminators, overly high baud rates or electrical noise. If errors occur, adding a terminator and/or operating at a lower baud rate will usually help.

Analog I/O Connections

The Industrial Control Interface (Option 1) includes three analog outputs and two analog inputs. These features can only be used if an external +24 V_{DC} power supply is connected to the BGA244. The analog I/O signals are located on C6 and C7. There are a number of different parameters that can be set for the analog inputs and outputs.

Pin	Signal
C7-1	Analog In 1 +
C7-2	Analog In 1 -
C7-3	Analog In 2 +
C7-4	Analog In 2 -
C7-5	Analog Out 1 +
C7-6	Analog Out 1 –
C7-7	Analog Out 2 +
C7-8	Analog Out 2 –
C6-3	Measure Out +
C6-2	Measure Out -

ANALOG I/O PINOUT

Analog Output

There are three separate Analog Outputs: Measure Out, Output 1 and Output 2. These can be independently set as voltage or current outputs. Measure Out is always linked to the Instrument Mode measured value. Outputs 1 and 2 can be linked to one of several different measured parameters or set explicitly by the user. The output full scale ranges can be scaled to match external devices. See *Analog I/O* (page 78) for information on configuring the outputs.

Voltage Outputs

The voltage outputs are unipolar and are ground referenced at the BGA244. The minus (–) outputs are connected to the BGA244s chassis ground. Avoid connecting the minus outputs to ground at the destination to avoid ground loops.

The voltage outputs have a maximum drive current of 20 mA and can drive capacitive loads of up to 1µF without oscillation. The output voltage may be reduced by resistive losses for long cable lengths and high currents. Make sure that the wire size, length and load current do not create excessive errors.

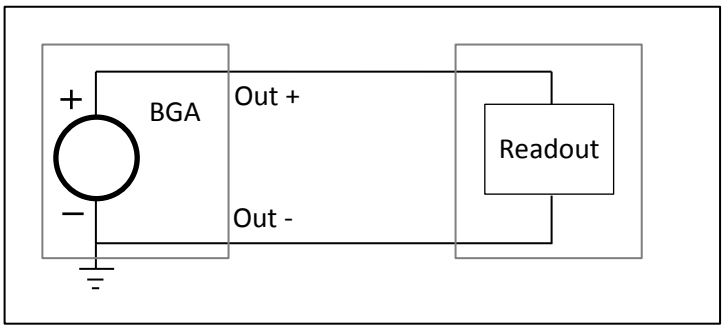


FIGURE 6: VOLTAGE OUTPUT

Current Outputs

The current outputs are unipolar and return to the BGA244s ground. The minus (–) outputs are connected to the BGA244s chassis ground. Avoid connecting the minus outputs to ground at the destination to avoid ground loops.

The current outputs have a compliance voltage of 16.5 V and can drive inductive loads up to 50 mH without oscillation. The maximum load resistance, including cable resistance, is 825 Ω. Cable resistance can be large depending on the length and wire size. Make sure that the cable resistance plus the load resistor is less than 825 Ω.

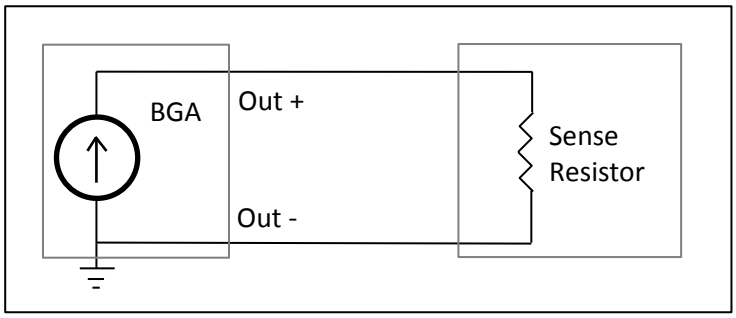


FIGURE 7: CURRENT OUTPUT

Analog Input

There are two separate Analog Inputs: Input 1 and Input 2. These can be independently set to measure voltage or current inputs. An internal loop power voltage source can be enabled for current input. Inputs 1 and 2 can be read on the front panel or over the computer interfaces. They can also be linked to a pressure transducer to monitor gas pressure. See *Analog I/O* (page 78) for details on configuring the inputs. See *Pressure Transducers* (page 31) for details on connecting pressure transducers to the analog inputs.

Voltage Input

The voltage input measures the differential voltage between the plus (+) and minus (-) lines. The input voltage range of either of the inputs is -0.1 to +20 V relative to ground. The differential voltage range from (+) to (-) is -2 to +10.2 V. This allows measurement of signals that are biased above ground.

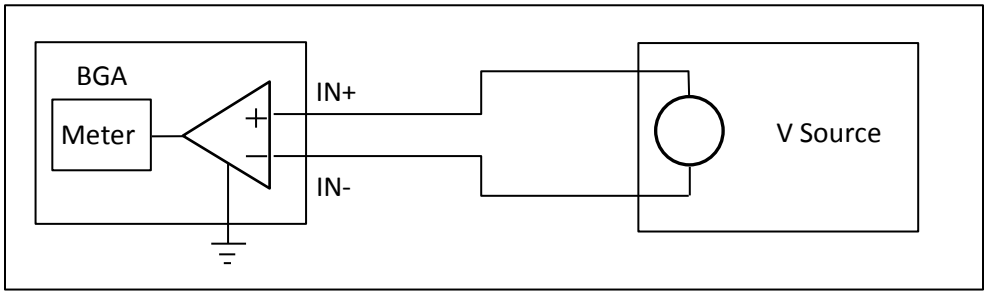


FIGURE 8: VOLTAGE INPUT

Current Input

The current input measures the absolute value of the current from the plus (+) input to the minus (-) input. The signal can be either polarity, with a maximum of 24 mA. The voltage range at each input must be between -0.5 and + 20 V; the burden voltage is 5.5 V for 20 mA. The wide voltage range and low burden voltage allows for multiple sense resistors or an external power supply in series with the current loop.

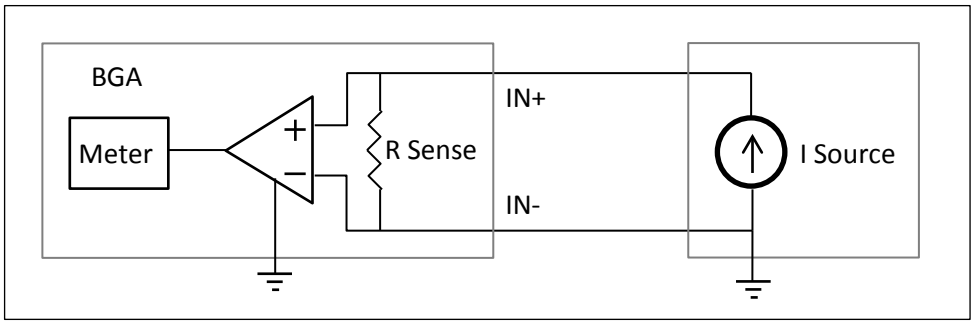


FIGURE 9: CURRENT INPUT

Current with Loop Power Voltage Source

Current Input with Loop Power is a special configuration of the current input mode that allow both signal and power to be transmitted over a pair of wires.

The Loop Power voltage source is ground referenced at the BGA244 and requires that the measured current returns to the minus (–) input. Devices that ground either current loop lead or require a floating loop power supply must use an external supply.

> **Hint:** In general, devices using this feature should float with respect to the BGA244's ground. This feature may not operate properly if either current loop lead is connected to ground.

The maximum current amplitude is 24 mA. The Loop Power supply can be set between 6 and 19 V with a maximum output current of 50 mA.

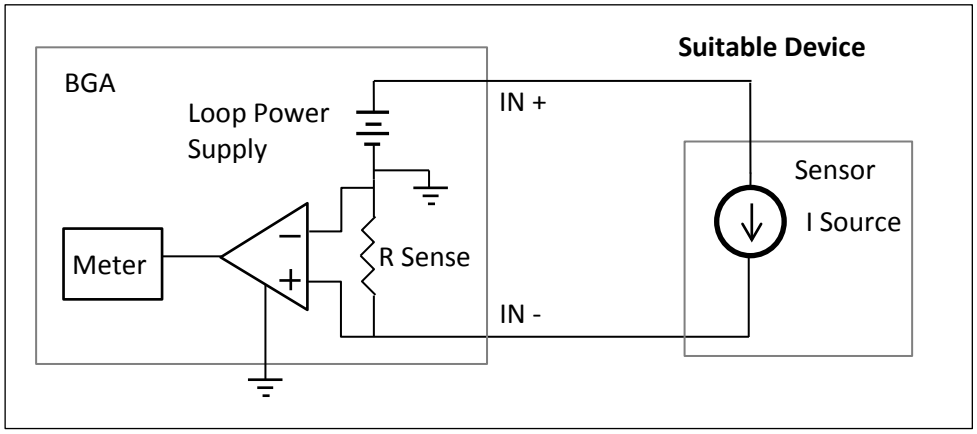


FIGURE 10: CURRENT INPUT W/ LOOP POWER (SUITABLE DEVICE)

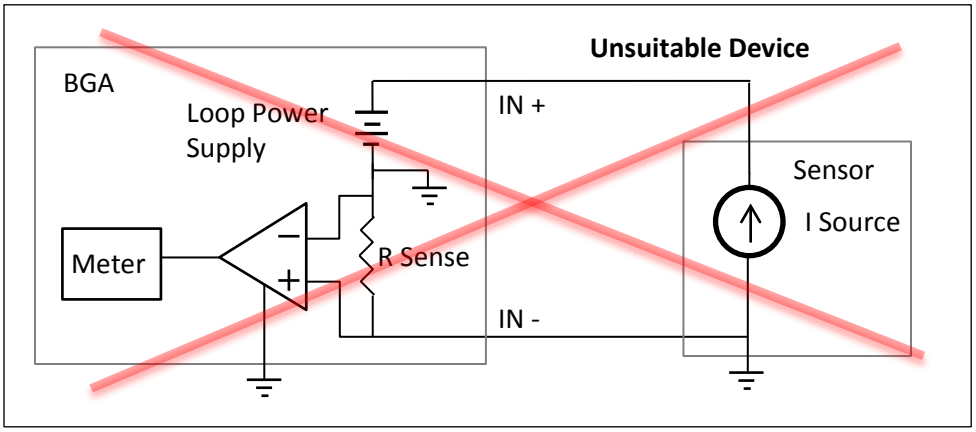


FIGURE 11: CURRENT INPUT W/ LOOP POWER (UNSUITABLE DEVICE)

Event Relays

There are two separate SPDT relays that are linked to the BGA244's Event 1 and Event 2 conditions. Events can be configured to switch for things like exceeded limits, loss of the measurement signal and system faults. They can also be directly set and cleared on the front panel or over the computer interfaces. See *Events* (page 53) for detail on configuring and controlling the Event Relays.

Pin	Signal
C8-1	Relay 1 Normally Open
C8-2	Relay 1 Common
C8-3	Relay 1 Normally Closed
C8-4	Relay 2 Normally Open
C8-5	Relay 2 Common
C8-6	Relay 2 Normally Closed

EVENT RELAY PINOUT

The relays are floating with respect to each other and chassis ground. Each relay consists of a common, a normally open and a normally closed connection. Normally open and normally closed refer to the relay in the de-energized state.

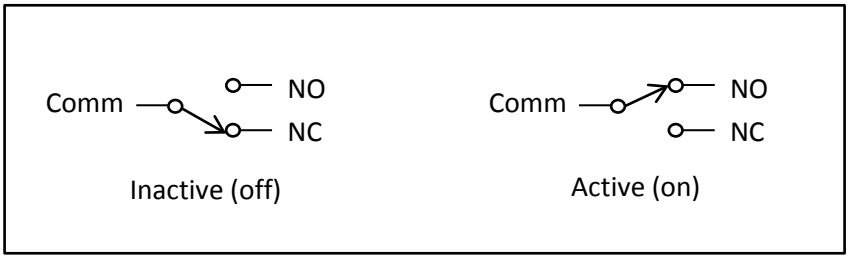


FIGURE 12: EVENT RELAY CONTACTS

The Event relay contacts are rated for the following conditions.

Max Switching Power	30 W, 62.5 VA
Max Switching Voltage	60 V_{DC}, 42.4 V_{PK}, 30 V_{AC}
Maximum Switching Current	1 A
Maximum Carrying Current	2 A
Lifetime (42 V_{DC}, 0.1 A resistive load)	10^6 operations

Switching high power loads can dramatically reduce the relays lifetime. If driving an inductive load, make sure to use catch diode to minimize inductive fly-back.

Common uses of the relays include:

- Turning on an alarm when a limit is exceeded
- Opening a valve to control a process
- Computer control of devices

Pressure Transducers

In some cases real time monitoring of the gas pressure can improve measurement accuracy. The simplest way to do this is by connecting a pressure transducer to one of the BGA244's analog inputs. This feature is only available for units with Industrial Control Interface (Option 1) installed and 24 V power. Using the voltage or current analog inputs, the BGA244 can interface with a variety of different transducers. Scale factors for minimum and maximum pressures can be set, in either absolute or gauge pressure.

There is a wide variety of pressure transducers that can interface with the BGA244. Differences among them include gas fittings, pressure ranges and electrical connections. When selecting a pressure transducer, select one that matches the system operating pressure. Transducers typically have the best linearity and accuracy when not operated at their extreme limits.

Refer to *Analog Inputs* (page 78) for details on configuring the Analog Inputs.

Mounting Location

Locate the pressure transducer on the BGA244 side of any restriction to minimize offsets in the measured pressure. Make sure to account for any drop in pressure between the measured or regulated pressure and the BGA244 for large flow rates. Follow the proper installation procedure when connecting the transducer to the gas system as described in *Gas Fittings* (page 16). Install the pressure transducers following their manufacturer's instructions.

Types of Pressure Transducers

The choice of which pressure transducer to use largely depends on the application it will be used in. Transducers come in many different ranges, fittings and accuracies. Choose a transducer with good sensitivity and accuracy and that matches the operating pressure of your system. If possible, use a transducer that reads in absolute pressure to eliminate ambient pressure variation.

The BGA244 can interface to most pressure transducers that output a voltage or current within the nominal analog input range. The BGA244 includes a selectable loop power voltage source that can be used to power many current output transducers. Transducers of this type are the simplest to integrate with the BGA244.

Input	Minimum	Maximum
Voltage	0 V	10 V
Current	4 mA	20 mA

Voltage Output Transducers

Voltage output pressure transducers have separate signal and power connections. In addition, they often have a drain wire that connects to the cable shield. They require an external power supply.

The BGA244 supports transducers with a full scale output range that lies between 0 and 10 V. Voltages must always be ≥ 0 V (no bipolar outputs). The output can be scaled to either absolute pressure or gauge pressure.

Connect an appropriate power supply per the manufacturer's instructions. If needed the Drain wire can be connected to ground at the BGA244 ground lug (C1). Connect the Signal and Signal Return (or +/– Signal) to +/– In 1 or In 2 on the BGA244. Refer to *Analog Input* (page 27) for details on connecting the transducer to the BGA244. Configure the BGA244 as described below.

- Set the analog input to: Enabled, Voltage.
- Select Absolute or Gauge units, depending on the transducers specifications. If Gauge units are selected, make sure to enter the ambient pressure.
- Set the Min and Max to the transducers minimum and maximum pressure values.
- Check "Use as Pressure Gauge".
- Set the Analysis Pressure to the appropriate input (Analog Input 1 or 2).

Current Output Transducers

Current output pressure transducers come in several different configurations. They can have separate power and signal lines or the power can be provided in series with the signal lines (loop power). In addition, they may have a drain wire that connects to the cable shield.

The BGA244 supports current output transducers with a full scale range of 4 – 20 mA. Currents can be either positive or negative. The output can be scaled for absolute pressure or gauge pressure.

The BGA244 can provide a loop power voltage source (6 – 19 V) if the transducer can accept a ground referenced voltage. See the pressure transducers manufacturers' information for specific details. Refer to *Analog Input* (page 27) for details on devices that are loop power compatible with the BGA244.

> **Hint:** If either the + or – signal lines are connected to the pressure transducers body or drain wire, it probably won't work with the BGA244 loop power voltage source.

Transducers with External Power Supplies

Connect the appropriate power supply as described by the pressure transducer manufacturer. If needed, the Drain wire can be connected to ground at the BGA244 ground lug (C1). Connect the Signal and Signal Return (or +/– Signal) to +/– In 1 or In 2 on C7 on the BGA244. Refer to *Analog Input* (page 27) for details on connecting the transducer to the BGA244. Configure the BGA244 as follows.

- Set the analog input to: Enabled, Current
- Select Absolute or Gauge units, depending on the transducers specifications. If Gauge units are selected, make sure to enter the ambient pressure.
- Set the Min and Max to the transducers minimum and maximum values.
- Check: Use as Pressure Gauge.
- Set the Analysis Pressure to the appropriate input (Analog Input 1 or 2).

Transducers with Loop Power

Connect the transducer Signal (or +) wire to +In 1 or 2 on the BGA244. Connect the Return (or -) wire to –In 1 or 2 on the BGA244. If needed, the Drain wire can be connected to ground at the BGA244 ground lug (C1). Refer to *Analog Input* (page 27) for details on connecting the transducer to the BGA244. Configure the BGA244 as follows.

- Set the analog input to: Enabled, Current w/ Loop Power
- Set the Loop Power Voltage to the voltage specified by the pressure transducer manufacturer, typically 12-15 V.
- Select Absolute or Gauge units, depending on the transducers specifications. If Gauge units are selected, make sure to enter the ambient pressure.
- Set the Min and Max to the transducers minimum and maximum values.
- Check: Use as Pressure Gauge.
- Set the Analysis Pressure to the appropriate input (Analog Input 1 or 2).

Chapter 3: Operation Guide

BGA244 User Interface

Display and Display-less Version

The BGA244 comes either with a display (Normal) or without a display (Option 2). Both versions have the same capabilities and specifications. Each can be fully configured and monitored over a computer interface. The display version has a touch screen display that allows the user to set and display all settings and measurements.

The description of the BGA244 features in this chapter is directed toward the display version. *Chapter 5: BGAMon* (contains information on configuring either version of the BGA244 using the BGAMon software. *Chapter 6: Remote Programming* contains information on the remote commands that can also be used to configure either version.

Navigation

There are several navigation keys that are present on many of the pages to make it easier to navigate the different instrument functions of the BGA244. See *Manual Conventions* (page xv) at the beginning of this manual for a list of conventions used to describe the different functions of the interface. The following rules will help you navigate the menus.

- [HOME] returns you to the Home Page.
- [SETUP] take you to the configuration pages that aren't displayed on the Home page.
- [←] or back key returns up one level from the display you are currently on.
- [PAGE ↑] and [PAGE ↓] are used to scroll through a page that can't all be displayed on the screen at the same time.
- Different pages are referenced by their location in the interface hierarchy. (Home/Setup/Control Panel/Units) would be reached from the Home page by pressing [Setup] [Control Panel] [Units].

Help Screens

Most screens have a Help page associated with them accessed by a Help key. This page will have information about the settings and displayed parameters on the screen. The [Page ↑] and [Page ↓] are active if the Help screen is more than one page long.

Map of Interface Functions

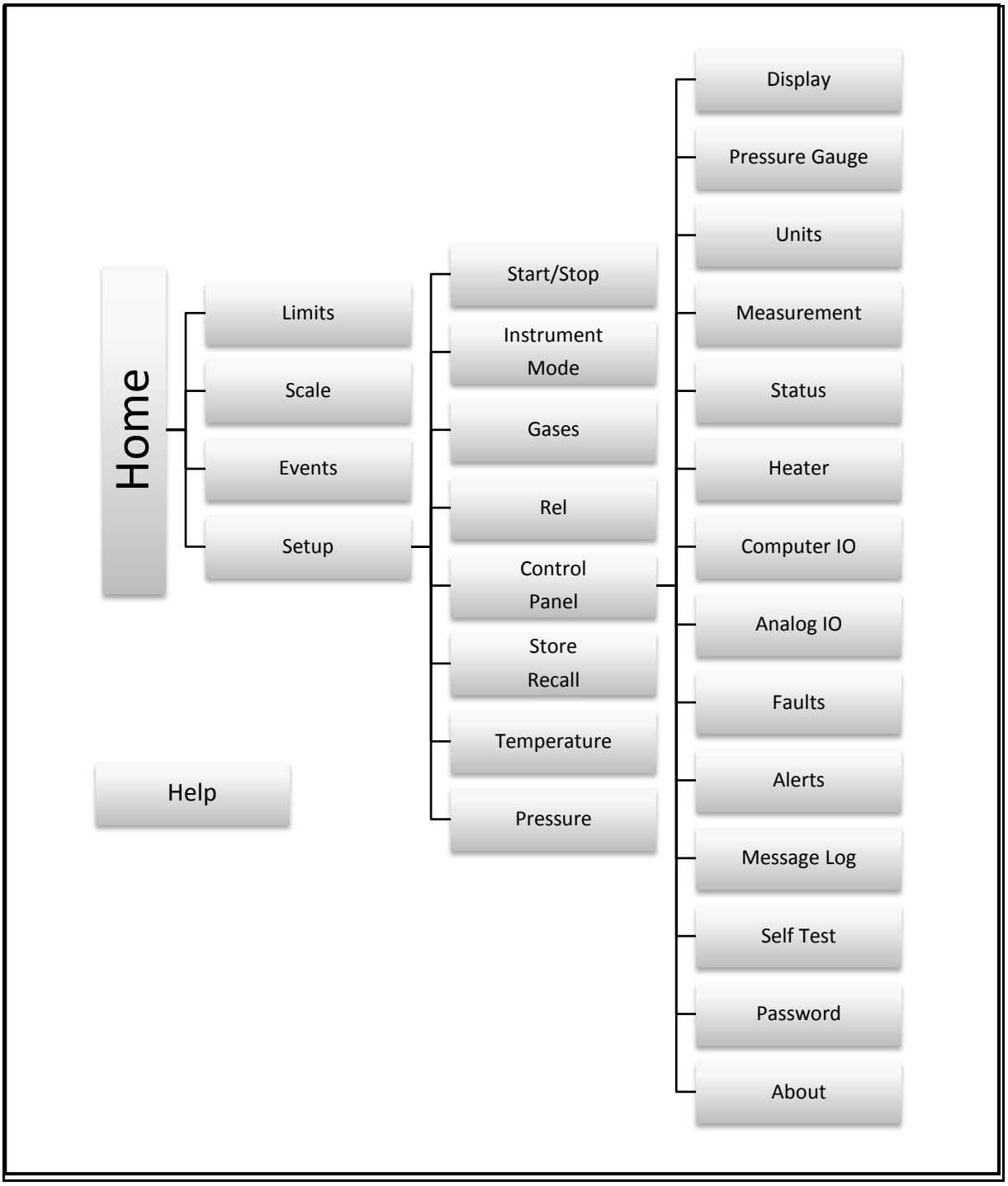
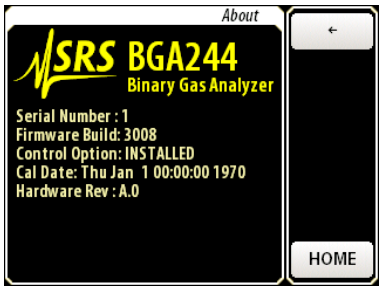


FIGURE 13: MAP OF USER INTERFACE FUNCTIONS

Power On



When power is first applied, a power-on splash screen will appear.

After a few seconds the "About" information page which displays the unit serial number, firmware version, installed options, calibration date and hardware version.

After about 15 seconds the currently selected Home page will appear.

The three LEDs also indicate power on behavior. This is especially useful for units without displays (Options 2). When power is first applied, the Power LED will light for ~ 1 second; followed by all 3 LEDs lighting for 5 seconds. At this time the Power LED should blinks once indicating the code is loading properly.

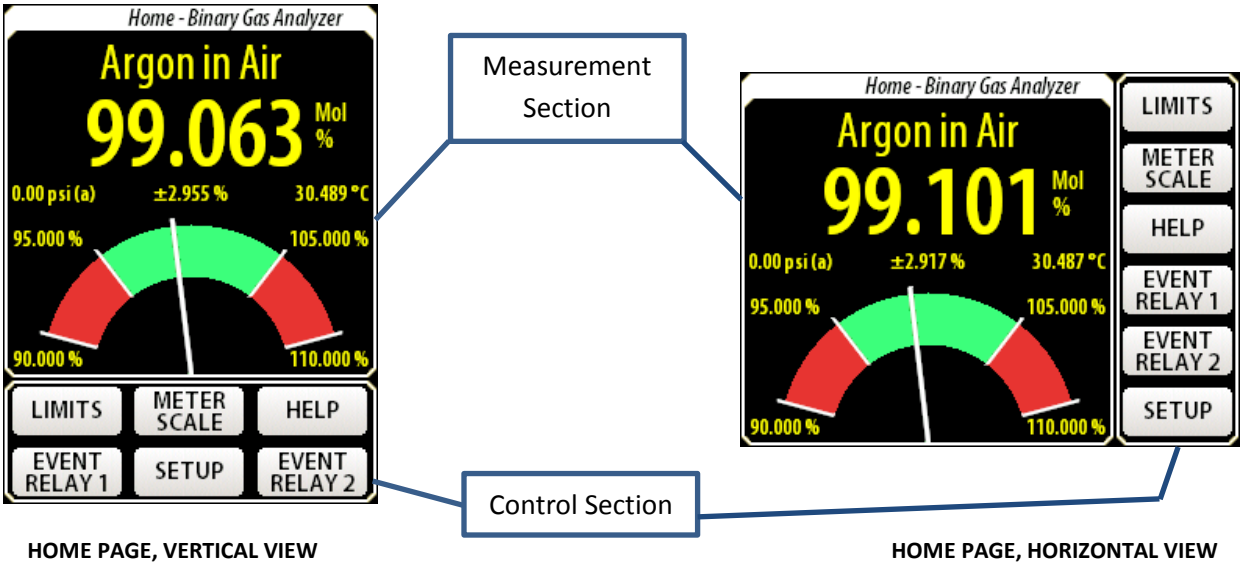
You can enter the screen calibration routine by pressing a finger to the screen when power is applied. Hold your finger down until the message "Release Screen to start Screen Calibration" appears, then follow the instructions to complete the routine. See Display later in this chapter for more information.

Appearance

The BGA244 uses a touch screen display to configure measurements and display measurement results. The Home page displays the primary measurements and has controls to navigate the instrument functions and secondary measurements. You can always return to the Home page directly from any page by pressing [Home].

Each Instrument Mode has a unique Home page. Home pages consist of a Measurement Section that is specific to the Instrument Mode and a Control Section that is common to all Instrument Modes.

There are two possible appearances of the display depending on the orientation: vertical, with the control section below the measurement section and horizontal, with the control section to the right of the display section.



HOME PAGE, VERTICAL VIEW

HOME PAGE, HORIZONTAL VIEW

FIGURE 14: BGA244 HOME PAGE

Measurement Section

The Measurement Section displays the operating mode, measurements and status information. The meter scale, limits and other functions are set using keys in the Control section. See the sections on *Binary Gas Analyzer* (page 40), *Gas Purity Analyzer* (page 43) and *Physical Measurements* (page 46) later in this chapter for details on each Instrument Mode.

Screen messages can appear in the Measurement section. These indicate operating states, errors or problems with the measurements. See *Screen Messages* (page 49) for details on these functions.

Control Section

The Control Section is common to all Home pages. The Control buttons are used to set parameters and access menus within the user interface. Press the appropriate button to access that control. See *Controls* later in this chapter for details on setting each control.

> **Note:** The touch screen on the BGA244 must be actually be pressed to activate functions. This is normally indicated by a key click or beep. Hovering over the button like you would on a cell phone or tablet won't activate the control.

Instrument Modes

The BGA244 can operate in one of three Instrument Modes: Binary Gas Analyzer Mode, Gas Purity Analyzer Mode and Physical Measurement Mode. The Instrument Mode determines the measurements made by the BGA244. Each Instrument Mode has a unique home page and measurement specific parameters (like gas selection, limits, and meter scale). See *Instrument Mode* (page 56) for more information.

Select Instrument Mode

Press [SETUP] to access the Setup page. This page has controls to configure the all of the instrument function besides those in the Control section.

Press [Instrument Mode ↓] to open the Instrument Mode list. Press the desired mode to select it. The currently selected mode is highlighted in yellow.

Binary Gas Analyzer

The Binary Gas Analyzer reports the fraction of one gas in a two gas mixture. Both gases must be known.

The Binary Gas Ratio is reported as the ratio of gas 1 in the mixture. Results are reported in percent (%), parts per million (ppm) or fraction (0 – 1.0). Go to (Setup/Control Panel/Units) to change the units. See the *Units* (page 71) for details on selecting units.

Principle of Operation

The speed of sound in an ideal gas can be approximated by:

$$W = \sqrt{\frac{\gamma RT}{M}}$$

Where W is the speed of sound, γ is the ratio of specific heat capacities ($\gamma = C_P/C_V$), M the molar mass, T the absolute temperature and R the ideal gas constant. For a gas mixture, γ and M are determined by the properties of each gas and their ratio within the mixture. By measuring the speed of sound and temperature of the gas mixture, and knowing the properties of each gas, the mole fraction of each gas can be precisely determined.

The speed of sound in real gases is somewhat more complicated. There are a number of gas specific effects that complicate the ideal case. These include thermo-viscous frequency shifts, temperature dependencies of heat capacity, dispersive effects and intermolecular (virial) effects that depend on both pressure and temperature. The BGA244 Factory Gas table contains data for these effects for nearly 500 different gases. For a detailed description on the science behind the BGA244s operation, see *Chapter 8: Theory of Operation*.

Binary Gas Analyzer Home Page

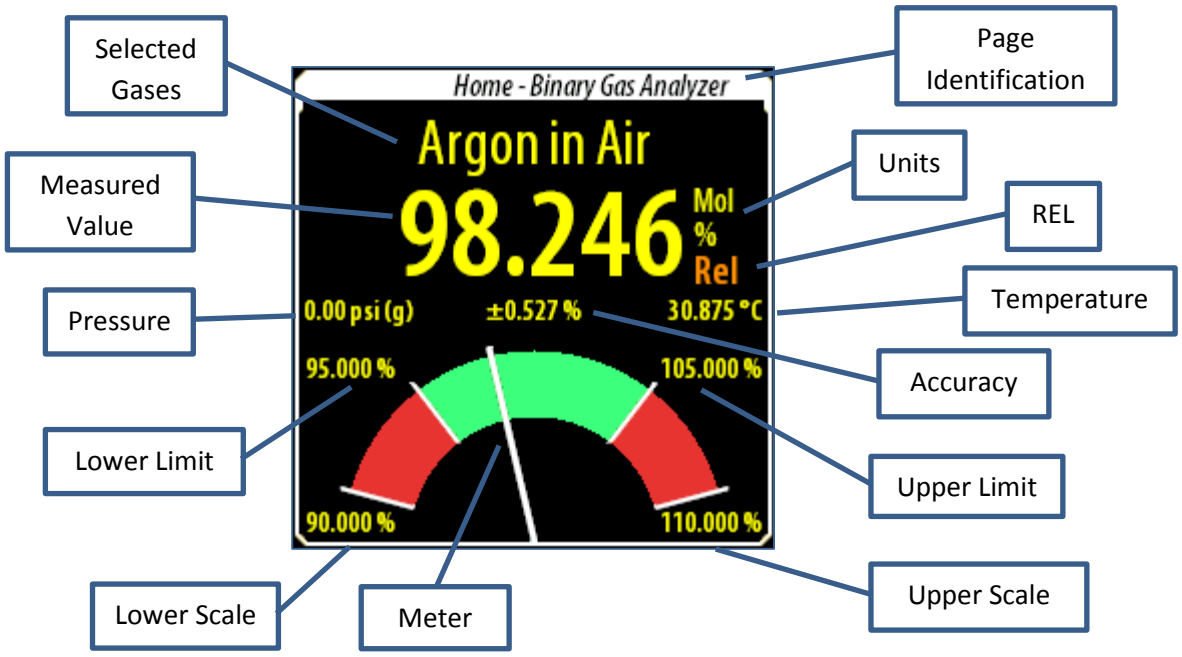


FIGURE 15: BINARY GAS ANALYZER HOME PAGE

- Page Identification: Binary Gas Analyzer.
- Selected Gases: Gas 1 in Gas 2. Refer to *Selecting Gases* (page 57) for details.
- Measured Value: Concentration of Gas 1 in the mixture.
- Units: %, ppm or fraction, and Mole/Mass fraction. See (Setup/Control Panel/Units) for units and (Setup/Control Panel/Measurement) for Mole/Mass fraction.
- REL: Visible when the REL function is active.
- Pressure: Measured or entered pressure used for analysis. See the *Pressure* (page 61) for more information.
- Temperature: Measured gas temperature.
- Accuracy: Estimated accuracy.
- Upper & Lower Limits: Set by [LIMIT] in the Control section. See *Limits* (page 52) for more information.
- Upper and Lower Scale: Set by [METER SCALE] in the Control section. See *Scale* (page 53) for more information.
- Meter: Graphical display of the Measured Value on a graph scaled by the upper and lower scale values. The red areas are set by the upper and lower limit values.

Details

This is a description of some of the items specific to the Binary Gas Analyzer Instrument Mode.

Range

The maximum range for the Binary Gas Analyzer is -2% to +102% or its equivalent in fraction or ppm. The 2% over range is to allow for measurement inaccuracies. Outside of this range the display will limit at > (max) or < (min) to indicate out of range.

Selecting gases

Both gases must be selected before measurements can be made. There are nearly 500 different gases contained in the BGA244 Factory Gas Table. Go to (Setup/Select Gas) to view the Gas Selection page. Here you can select Gas 1 and Gas 2 by name, chemical formula or CAS#. See *Selecting Gases* (page 57) for more information.

Note that the BGA244 reports the ratio of Gas 1 to the total mixture of Gas 1 and Gas 2. To report the concentration of Gas 2, press [SWAP GASES] on the Gas Selection page.

Molar Fraction vs Mass Fraction

The BGA244 can report the gas ratio in either mole or mass fraction. These differ by the atomic weights of the gases. Certain applications commonly use one or the other.

Go to (Setup/Control Panel/Measurement) to change between mole and mass fractions. See *Binary Gas Concentration* (page 72) for more details.

Accuracy Estimator

The BGA244 calculates a real time accuracy estimation of the gas ratio measurement. The accuracy estimation is based on temperature uncertainty of 0.1 °C and a pressure uncertainty of 1 psi.

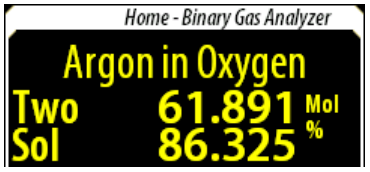
REL

The REL (relative) function can be used to zero the ratio measurement to a reference gas. This can be either a pure gas, or a gas blend with a known ratio. See the *REL* (page 59) for more information. The REL indicator only appears when the REL function is active.

Dual Concentrations

There are a few gas combinations where there are two valid molar ratios for a given speed of sound. The ratio of these gases can be accurately determined for certain concentrations, but there two ratio values for a portion of the range. Both ratios are equally valid as far as the BGA244 can determine.

If a dual concentration is detected, the BGA244 reports both ratios. Concentration 1 is the smaller value and is displayed on top. Concentration 2 is the larger value and is displayed on the bottom.



Gas Purity Analyzer

This analyzer reports the purity of a gas as measured by the ratio of its measured speed of sound to its ideal speed of sound. The gas species or its "ideal" speed of sound must be known. This instrument mode is useful when measuring relatively pure gases. Results are reported in percent (%), parts per million (ppm) or fraction (0 – ±1.0). Go to (Setup/Control Panel/Units) to change the units. Refer to *Units* (page 71) for details on selecting units.

Principle of Operation

The speed of sound of a pure gas at a known temperature and pressure is well known. Impurities will change this speed as a function of their mole fraction, molar mass and γ per the equation described in the Binary Gas Analyzer mode.

$$W = \sqrt{\frac{\gamma RT}{M}}$$

The definition of the Gas Purity in the BGA244 is:

$$\frac{\Delta W}{W} = \frac{measured\ speed\ of\ sound - expected\ speed\ of\ sound}{expected\ speed\ of\ sound}$$

Both the expected speed of sound and the measured speed of sound are normalized to NTP (20°C, 1 atm) before calculating the ratio to eliminate temperature and pressure dependencies. Since temperature and pressure affect each gas differently, it's important to specify the gas being measured for best accuracy. For a detailed description on the science behind the BGA244s operation, see the *Chapter 8: Theory of Operation*.

The gas purity is most sensitive when contaminants significantly heavier or lighter than the selected gas. If the purity measurement (*ΔW/W*) is positive, the contaminating gas is ordinarily lighter than the selected gas. Similarly if *ΔW/W* is negative, the contaminating gas is ordinarily heavier than the selected gas. Often a likely contaminating gas is known. Air, nitrogen, CO_2 or a previously purged gas may be an expected contaminate.

Gas Purity Analyzer Home Page

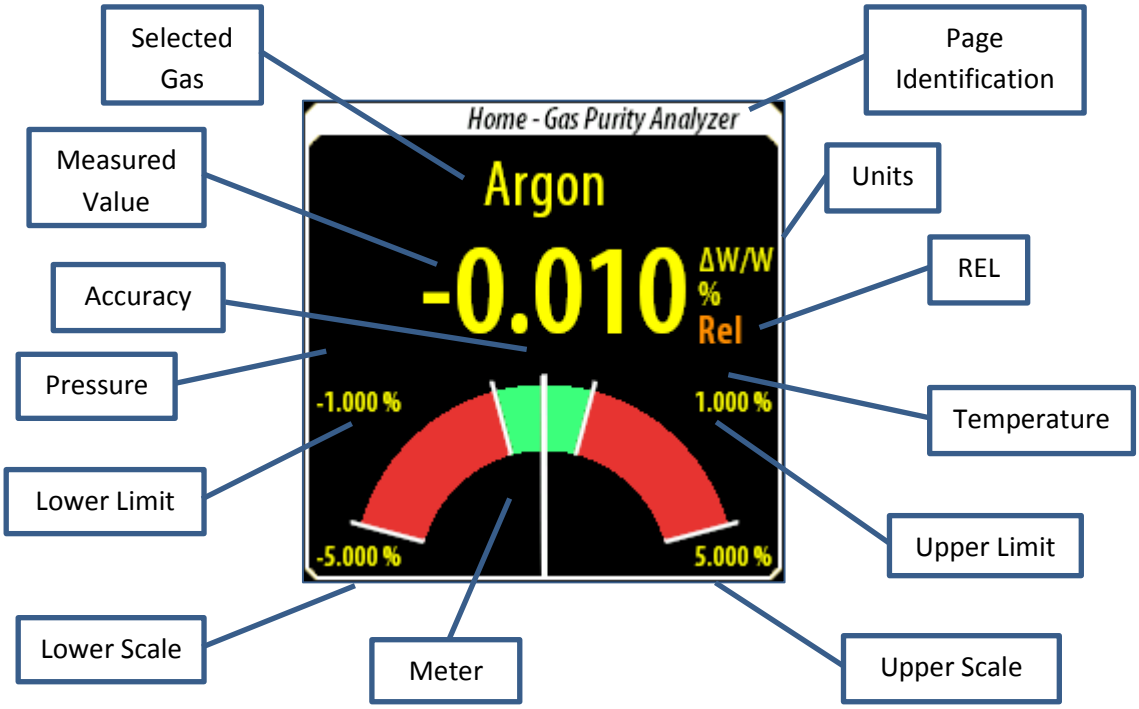


FIGURE 16: GAS PURITY ANALYZER HOME PAGE

- Page Identification: Gas Purity Analyzer.
- Selected Gas: Gas name or reference speed of sound. See the *Selecting Gases* (page 57) for details.
- Measured Value: $\Delta W/W$
- Units: %, ppm or fraction. See (Setup/Control Panel/Units) for unit selection.
- REL: Visible when the REL function is active.
- Pressure: Measured or entered pressure used for analysis. See the *Pressure* section later in this chapter for more information.
- Temperature: Measured gas temperature.
- Accuracy: Estimated accuracy
- Upper & Lower Limits: Set by [LIMIT] in the Control section. See the *Limits* section later in this chapter for more information.
- Upper and Lower Scale: Set by [METER SCALE] in the Control section. See the *Scale* section later in this chapter for more information.
- Meter: Graphical display of the Measured Value on a graph scaled by the upper and lower scale values. The red areas are set by the upper and lower limit values.

Details

This is a description of some of the items specific to the Gas Purity Analyzer Instrument Mode.

Select gas

Measurements can be made from a reference value, but whenever possible the gas species should be selected to improve the measurement accuracy. There are nearly 500 different gases contained in the BGA244 Factory Gas Table. Go to (Setup/Select Gas) to view the Gas Selection page where you can select the Gas by name, chemical formula or CAS#. See *Selecting Gases* (page 57) for information on selecting gases.

Gases not entered into the Gas Table can be measured by entering a reference speed of sound for the gas. Press [GAS=NONE], then either directly enter the speed of sound using the keypad or press [REL ZERO] to use the current speed of sound as a reference. Setting "GAS=NONE" eliminates any gas specific temperature and pressure corrections. Avoid using this if gas data is available for the best accuracy. If you want to zero the measurement from a reference value, use REL as described below rather than "GAS=NONE".

Table of sensitivities

This table shows *ΔW/W* (gas purity) for some common gases with a 1% contaminant.

TABLE 9: GAS PURITY ANALYZER SENSITIVITY

		1% Contaminant									
		H2	He	CH4	H2O	N2	O2	Ar	CO2	CF4	SF6
Selected Gas	H2	X	+0.00%	+0.00%	+0.00%	+0.00%	+0.00%	+0.00%	+0.00%	+0.00%	+0.06%
	He	-0.00%	X								
	CH4	-0.03%		X							
	H2O	-0.04%			X						
	N2					X					
	O2						X				
	Ar							X			
	CO2								X		
	CF4									X	
	SF6	-0.24%									X

Accuracy Estimator

The BGA244 calculates a real time accuracy estimation of the gas purity measurement. The accuracy estimation is based on temperature uncertainty of 0.1 °C and a pressure uncertainty of 1 psi.

REL

The REL (relative) function can be used to zero the measurement to a pure reference gas. See the *REL* section later in this chapter for more information on using this feature. The REL indicator only appears when the REL function is active.

Physical Measurements

The Physical Measurements Analyzer reports the physical measurements of a gas made by the BGA244. These include the

- Measured Speed of Sound
- Speed of Sound normalized to NTP (20°C, 1 atm)
- Temperature
- Pressure

The speeds of sound are reported in m/s, kph or mph. The temperature is reported in °C, °K or °F. The pressure is reported in psi, atm, bar, Pa, mmHg or torr. Go to (Setup/Control Panel/Units) to change units. See *Units* (page 71) for more details.

Principle of Operation

The measured speed of sound, temperature and pressure are the raw values used by the BGA244 to calculate gas mixtures and gas purity. The normalized speed of sound is computed from these measurements and data on the selected gas to compensate for temperature and pressure variations.

The normalized speed of sound is typically the most useful measurement, since it can be compared to data taken at other temperatures and pressures. It is computed for NTP (20°C, 1 atm). Since temperature and pressure affect each gas differently, it's important to specify the gas being measured for best accuracy. For a detailed description on the science behind the BGA244s operation, see the Chapter 8: *Theory of Operation*.

Physical Measurements Analyzer Home Page

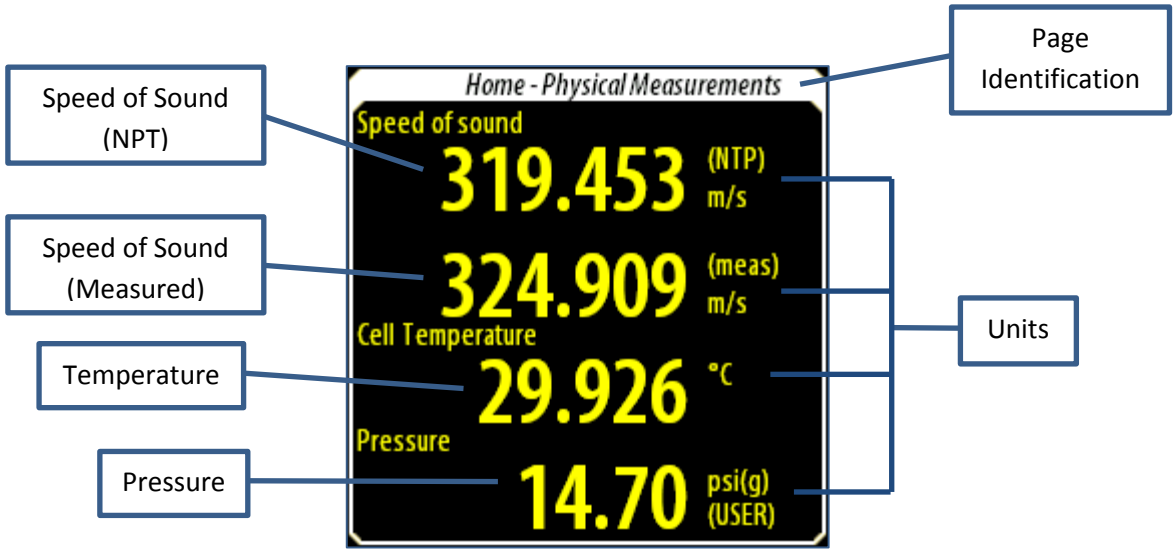


FIGURE 17: PHYSICAL MEASUREMENTS HOME PAGE

- Page Identification: Physical Measurements Analyzer.
- Speed of Sound Normalized to NTP (20°C, 1 atm).
- Measured Speed of Sound.
- Temperature: Measured gas temperature.
- Pressure: Measured or entered pressure used for analysis. See the *Pressure* section later in this chapter for more information.
- Units: See (Setup/Control Panel/Units).

The Upper and Lower Limits are not displayed in Measurement section since there is no graph, but they are active. See *Limits* (page 52) for more information.

Details

This is a description of some of the items specific to the Physical Measurements Instrument Mode.

Select gas

Measurements can be made from a reference value, but whenever possible the gas species should be selected to improve the measurement accuracy. There are nearly 500 different gases contained in the BGA244 Factory Gas Table. Go to (Setup/Select Gas) to view the Gas Selection page where you can select the Gas by name, chemical formula or CAS#. See *Selecting Gases* (page 57) for information on selecting gases.

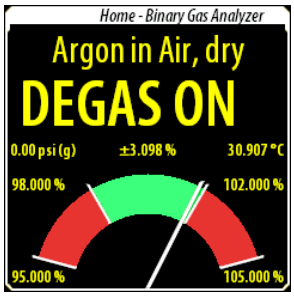
Gases not entered into the Gas Table can be measured. Press [GAS=NONE] to enter an unknown gas. Setting “GAS=NONE” removes any gas specific corrections and only corrects using the ideal gas law. Avoid using this if gas data is available for the best accuracy. If the gas is a mixture of several gases, specify the dominant gas species for best results.

Screen Messages

There are a variety of operating conditions that can be reported by the BGA244 (display versions only). There are several groups of messages including Analysis, Entry, Fault and Alert messages.

There are two types of screen messages. Normal messages appear as yellow or red text on the screen overwriting part of the Home page. These are notifications only and are referred to as “Messages”. Other messages are dual purpose, being both a notification as well as a navigation button. Pressing them will take you to the relevant page where more details are available. These are referred to as “Message Buttons”.

Analysis Messages



Messages appear in the measurement section to indicate something is affecting analysis within the BGA244. These items include user settings that may halt analysis, loss of signal and other analysis errors. All of these messages appear as text in the numeric display portion of the display.

Degas On

This indicated that the Degas heaters are on and measurements can’t be made. To return to the normal operating state, turn off the Degas heaters. See *Heater* (page 75) for more details.

>102%, <-2%

>102% or <-2% (or their equivalent in ppm or fraction) indicate that the binary gas measurement is out of range for the selected gas combination. This can be caused by measurement inaccuracies especially in gases with similar speeds of sound or an additional contaminating gas(es) in the cell or if the wrong gas(es) have been selected.

No Signal

This indicates that the BGA244 cannot recover the acoustic signal or identify a valid speed of sound for the gas. This most often occurs if the gas pressure in the cell is too low. See *Troubleshooting* (page 173) if this message is displayed with adequate gas pressure.

Invalid

This indicates that the BGA244 cannot calculate a valid solution for the gas concentration given the measured speed of sound (Binary Gas Analyzer only). Usually this only appears for a brief instant after a major disruption of the signal occurs. See *Troubleshooting* (page 173) if this message remains on for more than a few seconds.

Bad Pressure

This indicates that the measured pressure is invalid. It's usually caused by a problem with a pressure transducer or wiring connected to an Analog Input. See *Pressure* (page 62) for more information.

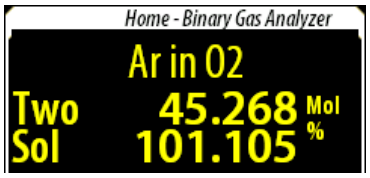
Condensation

This indicates that one or both of the gases is nearing its condensation point. When condensation occurs the BGA244 cannot correctly calculate the gas concentration, gas purity or normalized speed of sound. Refer to *Condensation* (page 93) for information on dealing with this problem.

Other Messages

Two Sol

Two Sol (Two Solutions) indicates there are two valid molar ratios for a given speed of sound. This can only occur for binary gas measurements. Concentration 1 is the smaller value and is displayed on top. Concentration 2 is the larger value and is displayed on the bottom. This only occurs for a few gas pairs with similar masses, but different γ's. Refer to *Gases* (page 91) for more information.



System Fault

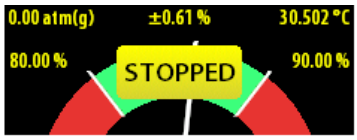
This Message Button indicated that a serious problem has occurred with the BGA244. Pressing [SYSTEM FAULT] takes you to the Fault page. See *Faults* (page 82) for more details.

Alert

This Message Button indicates that non-critical problem has occurred. Pressing [ALERT] takes you to the Alert page. See *Alerts* (page 84) for more details.

Stopped

This indicated that the BGA244 has been placed in the STOP mode and no measurements are being made. Pressing the [STOP] key will take you to the Setup page where the Run mode can be selected. Refer to RUN|STOP (page 56) for more details.



Invalid Entry

This message appears if an entered number is outside the allowable range. The minimum or maximum value for that entry is displayed.

LED Blink Codes

The Power and Error status LEDs are used to indicate the operating state of the BGA244. They can indicate power faults, system faults, analysis errors and communication errors using blink codes. These features are active on all units and are especially useful for units without a display (Option 2). See *Figure 1* (page 6) for the LED locations.

Normal Behavior

When power is first applied, the Power LED will light for ~ 1 second; followed by all 3 LEDs lighting for 5 seconds. At this time the Power LED should blinks once indicating the code is loading properly then operational.

After this the Power LED remains on. The Comm (Communications) LED will flash during communication over any of the computer interfaces. The Error LED will remain off unless an error occurs.

ERROR LED Codes

These codes use the red ERROR LED to indicate various errors.

- System Fault: The ERROR LED is continuously on as long as the condition persists.
- Stopped, Degas, Invalid, Bad Pressure, Condensation or No Signal: The ERROR LED flashes at about 4 Hz as long as the condition persists.
- Communication Error: ERROR LED flashes once for each error.

POWER LED Codes

The BGA244 can indicate if the USB or +24 V power supplies are out of range using blink codes on the Power LED. Refer to *External Power Supply Faults* (page 82) for details. Note that the BGA244 must have a minimum power supply voltage to generate the blink codes.

- Active Power Supply Fault: The POWER LED will flash at about 4 Hz.

Minimum Operational Voltage: USB ≥ 3.5V, +24 ≥ 18 V

USB Fault: Voltage < 4.5V or > 5.3V

+24 V Fault: Voltage < 20V or > 26V

Controls

Each Home page has the same Control section. Control buttons are used to access menus within the user interface. Several functions can be directly accessed from the Home page while others are accessed through the Setup Menu.

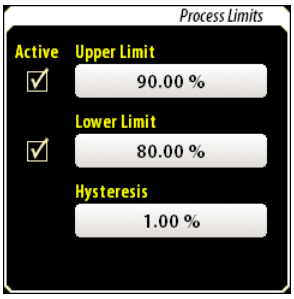
Note that the Physical Measurements Home page omits the Meter Scale control button since there is no meter. It replaces it with a Pressure Meter button.

Limits

Process limits are used to indicate that the measurement is above or below a set value. Limits serve two purposes in the BGA244. They are displayed on the meter to provide visual feedback (Binary Gas and Purity Analyzers) and are used in Events to control external devices.

The [LIMITS] button on the Home page is a dual purpose control. At any time, pressing [LIMITS] takes you to the Process Limits Page where the limit values can be entered. Additionally, the [LIMIT] button will turn red if either the Upper or Lower Limit is exceeded.

Process Limits Page



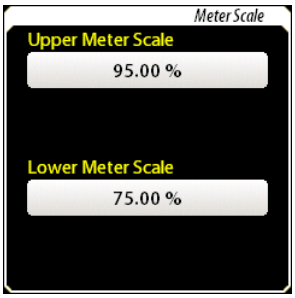
The upper and lower limits are set in units of the measured value. Each limit can be separately enabled. The Hysteresis value provides a guard band around the limit thresholds to avoid oscillating between the limit & non-limit states. This is particularly helpful when using the Event Relays to stop relay chatter.

The Upper Limit must be greater than the Lower Limit and within the operating range of the measured parameter. If not, an “Invalid Entry” message will appear with guidelines for a legal value.

If the Upper Limit has been exceeded, the measurement must drop below {Upper Limit – Hysteresis} to deactivate the Upper Limit. Similarly if the Lower Limit has been exceeded, it must rise above {Lower Limit + Hysteresis} to deactivate the Lower Limit.

Example:
For an upper limit set at 90% and the hysteresis set at 5%. If the measurement increased above 90%, the Upper Limit would be active. When deceasing, the Upper Limit wouldn’t deactivate until the measurement dropped below 85%.

Scale (Binary & Gas Purity)



The [SCALE] button on the Home page opens the Meter Scale page. The Upper and Lower scale values are set in units of the measured value for the Binary Gas Analysis and Gas Purity modes. This control doesn't appear for the Physical Measurements mode. The Upper Scale value must be greater than the Lower Scale value and within the operating range of the measured parameter. If not, an *Invalid Entry* message will appear with guidelines for a legal value.

Pressure (Physical Measurements)

The [PRESSURE METER] button on the Home page opens the Analysis Pressure Meter page. See *Pressure* later in this chapter for more details.

Help

[HELP] takes you to a Help screen for the particular page you are on. Each Help page describes the parameters and settings for that page. There may also be suggestions to resolve problems or errors found on that page.

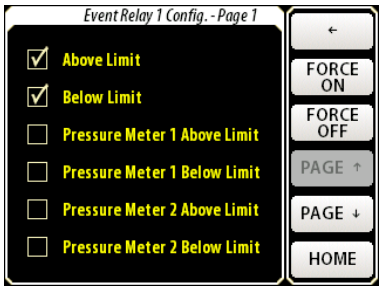
Event Relay 1 & 2

The Event Relays can be used to control external devices that depend on different conditions in the BGA244. These conditions can be individually enabled and include things like exceeded limits, loss of the measurement signal and system faults. There are two independent events relays: Event Relay 1 and Event Relay 2. If any enabled conditions are true, the Event Relay becomes active.

If the Industrial Control Option (Option 1) is not installed or +24 V_{DC} is not present, the [Event Relay] buttons are greyed out and the Event Relays are not active.

The [EVENT RELAY] buttons are dual purpose controls. Pressing them takes you to the Event 1 or Event 2 configuration page where the event conditions are set. If an event is currently active, that event button will turn red as an indicator. If the Event Relay is in a Force On or Force Off state, that button will turn yellow to indicate that condition.

Event Relay Configuration Pages



Event 1 and Event 2 are set independently and have separate configuration pages. Any of the enabled conditions can activate an event. The following conditions can be selected. Use the [Page ↑] and [Page ↓] keys to navigate the Event list.

Any active condition in the Event list is displayed in red, whether it is enabled or not.

- Above Limit: Activates if the measured value is above the process upper limit. Setting the upper limit is described in *Limits* (page 52).
- Below Limit: Activates if the measured value is below the process lower limit. Setting the lower limit is described in *Limits* (page 52).
- Pressure Meter 1 Above Limit: Activates if Pressure Gauge 1 is above the upper pressure limit. This selection is only available if Pressure Gauge 1 has been configured. Configuring the pressure gauge and limits is described in *Pressure* (page 61).
- Pressure Meter 1 Below Limit: Activates if Pressure Gauge 1 is below the lower pressure limit. This selection is only available if Pressure Gauge 1 has been configured. Configuring the pressure gauge and limits is described in *Pressure* (page 61).
- Pressure Meter 2 Above Limit: Activates if Pressure Gauge 2 is above the upper pressure limit. This selection is only available if Pressure Gauge 2 has been configured. Configuring the pressure gauge and limits is described in *Pressure* (page 61).
- Pressure Meter 2 Below Limit: Activates if Pressure Gauge 2 is below the lower pressure limit. This selection is only available if Pressure Gauge 1 has been configured. Configuring the pressure gauge and limits is described in *Pressure* (page 61).
- Temperature Above Limit: Activates if the Temperature Gauge is above the upper temperature limit. Configuring the Temperature gauge and limits is described in *Temperature* (page 64).
- Temperature Below Limit: Activates if the Temperature Gauge is below the lower temperature limit. Configuring the Temperature gauge and limits is described in *Temperature* (page 64).
- System Fault: Activates if there is a serious fault with the BGA244. See *Faults* (page 82) for a list of possible System Faults.
- No Signal: Activates if the BGA244 cannot determine the speed of sound in the gas. This can occur if the gas pressure in the BGA244 is too low. See *Troubleshooting* (page 173) for possible causes.

Force On, Force Off Buttons

There are two additional buttons that manually control the Event Relays regardless of any event conditions. [FORCE ON] sets the relay to the ON state. [FORCE OFF] sets the relay to the OFF state. The selected Force button will turn yellow, as will the Event button on the Home page to indicate the force condition. Press the button a second time to release the force condition.

Event Relay Connections

Each Event Relay has three pins: normally open (NO), normally closed (NC) and common (COM). In the OFF state, NC is connected to COM and NO is open. In the ON state, NO is connected to COM and NC is open. The relays are in the OFF state when the BGA244 is powered off.

See *Event Relays* (Page 30) for details on wiring the relays to outside circuits. See the *Specifications* section for details on relay ratings and life time.

Using Event Relays

Event Relays are normally used to signal an out of range or error condition. They could be connected to a bell or horn to notify an operator of an out of range condition, or connected to a valve to increase the flow of a gas.

A common set up for Event 1 and Event 2 would be as follows.

- Event 1: Above Upper Limit, Below Lower Limit
- Event 2: System Fault, No Signal

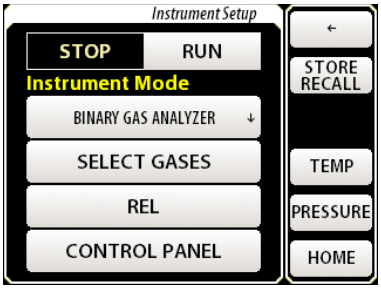
The Event 1 Relay indicates if the measured value was above or below the set limits and Event Relay 2 would indicate that there was a problem with the measurement.

Setup

[SETUP] takes you to the Instrument Setup page which is described in the following section. From here you can access the remaining controls and settings of the BGA244.

Setup

The Setup menu accesses all the BGA244 controls that aren't directly available on the Home page. Press [SETUP] on the Home page to reach the Instrument Setup page.



The most important functions in the BGA244 can be directly accessed from the Setup page. Less commonly used functions are reached via the Control Panel. See the *Map of Interface Functions* (page 36) for the locations of different function controls.

Run|Stop

It's occasionally necessary to stop analysis and output updates. For example, you may not want alarm relays to activate or analog outputs to pin while changing gas cylinders or performing other system maintenance. Pressing [RUN|STOP] toggles between the run and stop states. When the BGA244 is stopped, a [STOPPED] message button will appear on the Home Page. Pressing this button takes you to the Setup Page where the [RUN|STOP] control is located.

When the BGA244 is stopped the following functions do not update:

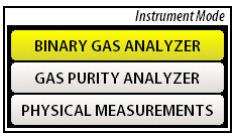
- Gas Ratio, Gas Purity, Speeds of Sound
- Event Relays
- Analog Outputs
- Temperature Readings

Instrument Mode

The BGA244 can operate in one of three Instrument Modes: Binary Gas Analyzer, Gas Purity Analyzer and Physical Measurement. Each Instrument Mode has a unique Home page and measurement specific parameters (gas selection, limits, and meter scale).

Select Instrument Mode

Press [INSTRUMENT MODE ↓] to open the Instrument Mode list. Press the desired mode to select it. The currently selected mode is highlighted in yellow.



Selecting Gases

Measurements made with the BGA244 ordinarily require selecting the gases to be measured. Two gases must be selected for the Binary Gas Analyzer; a single gas is normally selected for the Gas Purity Analyzer and Physical Measurements. Each Instrument Mode has its own unique gas selection. So if you enter a gas for the Binary Gas Analyzer mode, it won't appear for either the Gas Purity Analyzer or Physical Measurements.

The BGA244 Factory Gas Table contains nearly 500 different gases. Each entry includes the formula, common name, CAS # and up to two alternate names. All of these are scanned when selecting a gas. Besides naming information, an array of physical properties is stored with each gas for calculating gas ratios and speeds of sound. *Appendix A* contains a list of Factory Gas Table gases and a description of all of the gas properties.

Additional gases can be added into the User Gas Table. These can include mixtures or blended gases, made up of 2 or more single species gases. See *User Gases* (page 113) for information about adding new gases to the User Gas Table.

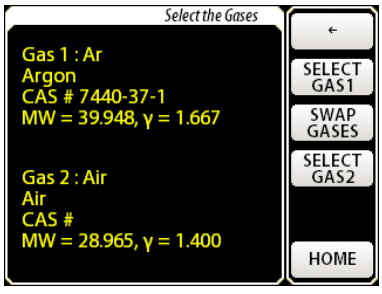
To view the currently selected gas or gases go to (Setup/Select Gases). This page displays the information about the currently selected gas(es) or "Reference Gas = None" if no gas is selected.

The following information is displayed for each gas selected:

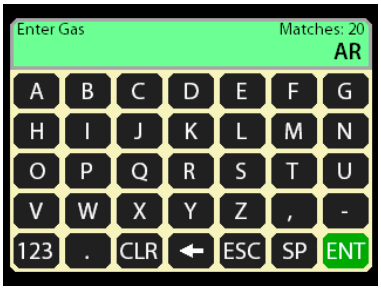
- Gas number (for Binary Gas Analyzer mode only)
- Chemical formula: The simple (non-structural) formula of the gas
- Common Name of the gas
- CAS # The CAS Number is a unique identifier for every chemical substance described in open scientific literature.
- MW (Molecular Weight) of the gas molecule in AMUs (for Binary Gas Analyzer mode only)
- *γ* (gamma): The ratio of specific heat capacities (for Binary Gas Analyzer mode only)
- Speed of Sound at NTP (for Gas Purity Analyzer and Physical Measurements modes only)

How to select gases

Gases are selected at (Setup/Select Gas(es)). Press [SELECT GAS 1], [SELECT GAS 2] or [SELECT GAS] to open the alpha-numeric keypad.



Begin typing the name, formula or CAS # of the desired gas. As you enter characters, the BGA scans the entire gas Table for matches to the entered text and displays that number in the “Matches” field. If no gases match the entered text it displays “Matches: 0”. If you press an incorrect key, press [←] to erase the last character or [CLR] to erase all characters.



When the number of matches is down to a manageable number (< 20 or so), press [ENT] or [ENTER]. This will open up a list of all of the matches from the gas table. Note that matches can occur at any position in the gas name, formula or CAS #. If there are more than 7 matches, use [Page ↑] and [Page ↓] to view the entire list. If you don’t see the expected gas, press [←] to return to the alpha-numeric entry window.

Select the desired gas by pressing its entry. This will enter the selected gas and return to the Select Gases page. If you wish to change the gas, press the desired gas selection key and re-enter the gas.

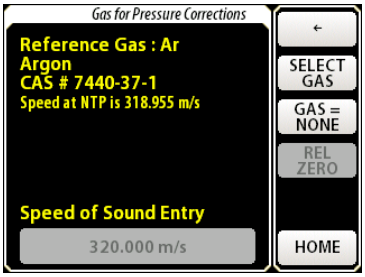
When selecting gases, User Gas Table gases will appear as “User/gas_name” to differentiate from a gas in the Factory Gas Table.

Swap Gases (Binary Gas Analyzer)

For the Binary Gas Analyzer Mode, results are displayed for the concentration of Gas 1 relative to the total mixture. If you want to view the concentration of Gas 2, press [SWAP GASES] which will exchange the Gas 1 and Gas 2 entries. This key only appears for the Binary Gas Analyzer.

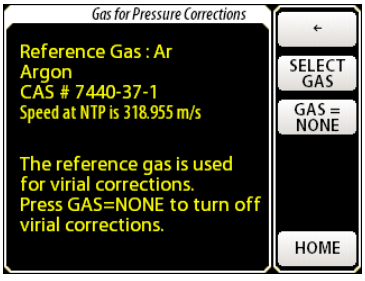
Gas = None (Gas Purity Analyzer)

For the Gas Purity Analyzer, gases without physical data can be measured by entering a Reference speed of sound at NTP. Press [GAS=NONE], then either directly enter the speed of sound using the keypad or press [REL ZERO] to use the current speed of sound as a reference.



Gas = None (Physical Measurements)

For Physical Measurements, gases without physical data can be measured by pressing [GAS = NONE].



REL

The BGA244 provides excellent accuracy using its internal calibration and its stored thermodynamic data. But there are circumstances where displaying deviations from an entered value may be useful. This can be used to track deviations from a reference gas or improve the measurement accuracy at a particular operating point. Typical uses for the REL function include:

- Setting a carrier gas to 0 or 100% when working with small concentrations of a dopant gas.
- Zeroing readings to a "reference mixture" and measuring the deviation from that value.
- Using a REL value to compensate for an unknown pressure.
- Using REL to measure deviations from a "reference point" when complete thermodynamic data isn't available for a User gas.

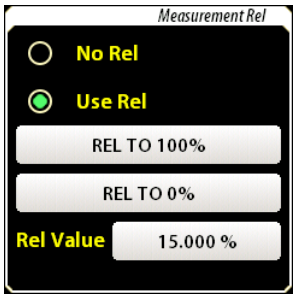
The REL function is available for the Binary Gas Analyzer and the Gas Purity Analyzer Instrument Modes. When active, the "REL" indicator is displayed below the measurement units as shown on the Home pages.

The REL function performs the following operation:

$$displayed\ value = measured\ value - Rel\ Value$$

A REL is typically performed using a reference gas, either a pure gas or a well known mixture. In general, REL works best when operating near the conditions that the REL was performed at. Large deviations in temperature, pressure or concentration may make the technique less effective. Situations and techniques where the REL function can improve measurement accuracy are described in the Chapter 4: *Application Guide.*

Binary Gas Analyzer



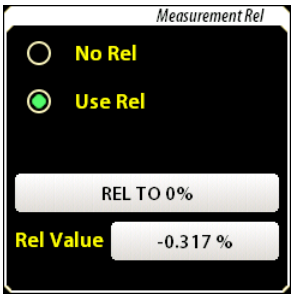
Press ◯Use REL or ◯No REL to select or deselect the REL function.

Press [REL TO 100%] to set the measured value to 100% (or 1000000 ppm or 1.0 fraction). The value required to force the displayed value to 100% is displayed in the [Rel Value] button in global ratio units.

Press [REL TO 0%] to set the measured value to 0% (or 0 ppm or 0.0 fraction). The value required to force the displayed value to 0% is displayed in the [Rel Value] button in global ratio units.

You can also directly enter the Rel Value between -110% and +210% (or their equivalent in ppm or fraction). This value will be subtracted from the measured value to produce the displayed value.

Gas Purity



Press ◯Use REL or ◯No REL to select or deselect the REL function.

Press [REL TO 0%] to set the measured value to 0%. (or 0 ppm or 0.0 fraction). The value required to force the displayed value to 0% is displayed in the [Rel Value] button in global ratio units.

You can also directly enter the Rel Value between -110% and +210% (or their equivalent in ppm or fraction). This value will be subtracted from the measured value to produce the displayed value.

Pressure

The speed of sound in an ideal gas is independent of pressure. The speed of sound in real gases does depend on pressure. For many gas(es) satisfactory measurements can be made without knowing the exact pressure. However to meet its specified accuracy for all gases, the BGA244 must know the gas pressure to within ± 1 psi (6.9 kPa). See the *Applications Guide* for information on the effects of pressure on measurement accuracy.

Pressure is the only external parameter that needs to be input to the BGA244 besides the gas species. It can be directly entered using the keypad or computer interface. Or a pressure transducer can be integrated with the BGA244 using one of the analog inputs (units with Option 1).

Direct entry of the pressure is well suited for processes that operate at a fairly constant, known pressure. Typically the pressure is known by the system design or by monitoring an external gauge. This is the only method available for units that do not have Option 1.

Other processes may experience pressure variations over time or operating conditions. These applications will benefit from integrating a pressure transducer using one of the BGA244's analog inputs. This provides a simple, integrated solution to provide the best accuracy across a range of operating conditions. Using an external pressure transducer requires the Industrial Control Interface (Option 1) and +24V. SRS offers a pressure transducer that is suitable for many applications (Accessory BGA-T), but there are many other transducers available. Refer to *Pressure Transducers* (page 31) for information on connecting a pressure transducer to the BGA244.

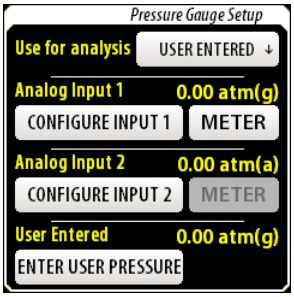
Gauge Pressure vs Absolute Pressure

The BGA244 uses the absolute pressure of the gas as part of its calculations. However pressure can be input in either absolute pressure units or in gauge pressure units combined with the ambient pressure. This is true for both direct entry of User pressure or when integrating a pressure transducer.

Absolute pressure is relative to vacuum while gauge pressure is relative to the ambient pressure outside the gauge. The correct pressure units (gauge or absolute) must be selected in the BGA244 to avoid errors. If gauge pressure units are selected, the ambient pressure must also be entered. Refer to *Pressure* (page 96) for details.

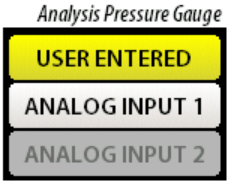
> **Hint:** If a pressure gauge or transducer can report negative pressures, it is reporting the gauge pressure. If it reports only positive pressures it can be either absolute or gauge. This should be listed on the pressure gauge specifications.

Press [PRESSURE] to access the pressure gauge setup menu. Here you can view the current pressure or select the pressure entry method for analysis and configure the external pressure gauge if needed. Pressure units are set on the Units page (Setup/Control Panel/Units section). Allowable units include psi, atm, bar, Pa, mmHg and torr.



Selecting Analysis Pressure

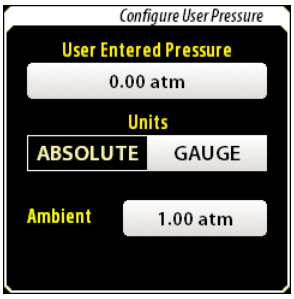
Press <Use for Analysis ↓> to select the pressure entry method. There are 3 choices: User Entered, Analog Input 1 and Analog Input 2. The currently select method is highlighted in yellow. The Analog Inputs will be grayed out unless they have previously been configured as pressure gauges.



User Pressure

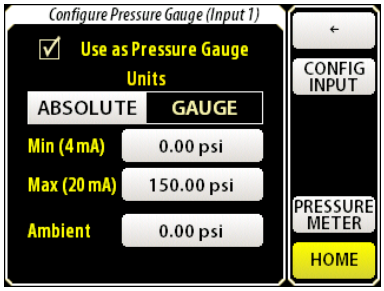
Press [ENTER USER PRESSURE] to manually enter the Pressure. Pressure can be entered in absolute pressure units (relative to vacuum) or in gauge pressure units (relative to ambient pressure). If you select gauge pressure units you must enter the ambient pressure.

Example: The display to the right shows a gauge pressure of 0 atm, with an ambient pressure of 1 atm (~14.7 psi).



Configure Pressure Gauge

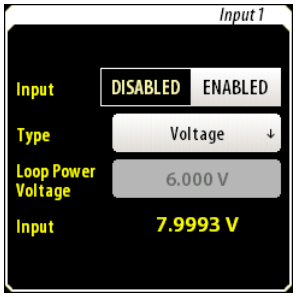
Press [CONFIGURE INPUT 1|2] to open one of the Configure Pressure Gauge pages. Typically only one of the two inputs is configured as a pressure gauge, but both selected can be if desired. Check the "Use as Pressure Gauge" box and select absolute or gauge pressure units. Be sure to enter the ambient pressure if using Gauge Pressure. Verify that the analog input is enabled and check that the Min and Max input format matches your transducer (V vs mA). If not, configure the input as described below.



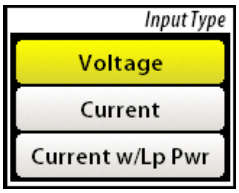
Assuming the formats match, enter the pressure values for the minimum and maximum analog input values. If the analog output of your pressure gauge doesn't match the span of the analog input, calculate what the pressure would be at those points.

Example:
Your pressure transducer outputs 0 - 5 V_{DC} for 0 - 50 psi
Set the following
Min (0V) = 0.00 psi
Max (10V) = 100.00 psi

Configure Input



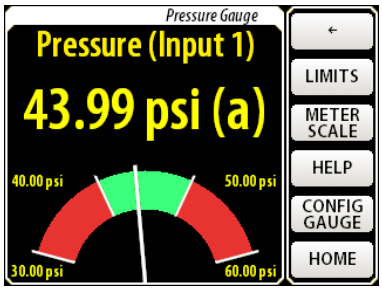
Enable the Analog Input. Press [CONFIG INPUT] to open the Configure Analog Input page. Press <Type ↓> to select the appropriate input type: Voltage, Current and Current w/ Loop Power. The currently select method is highlighted in yellow.



Certain pressure transducers can operate using loop power provided by the BGA244. This is the simplest type of transducer to integrate since it only requires 2 wires. See *Analog Inputs* (page 78) for details on different input types. If Current with Loop Power is selected, enter the appropriate loop power supply voltage.

An improperly configured analog input, broken pressure transducer or wiring can lead to out of range pressure readings. If this occurs, a “BAD PRESSURE” screen message will appear in place of the measurement and no results will be reported. There are also several alerts that can occur for the analog inputs. These normally indicate a problem with the device connected to the Analog Input or wiring, rather than the input itself. See *Analog Inputs* (page 78) for details.

Pressure Meter

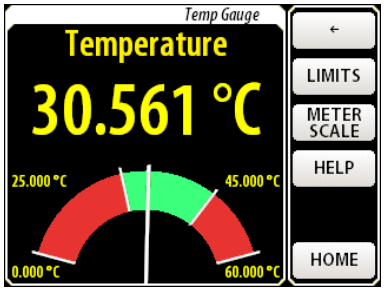


There are pressure meter pages associated with each analog input when it’s configured as a pressure gauge. Press [METER] on either the Pressure Gauge Setup or Configure Pressure Meter pages to view the pressure meter associated with that input. If an analog input is not configured as a pressure gauge that selection will be grayed out.

The Pressure Gauges each have a meter scale and limits similar to the Home page displays. Press [METER SCALE] to set the graph scale and [LIMITS] to set the Pressure Limit values. These are the over and under pressure limit values used on the Event Relay page.

Temperature

The cell temperature can also be displayed on a meter with limits and a scale. Press [TEMP] from the Setup page to view the temperature meter.



The Temperature Gauge has a meter scale and limits similar to the Home page displays. Press [METER SCALE] to set the gauge scale and [LIMITS] to set the Temperature Limit values. These are the over and under values limit used on the Event Relay page.

Store|Recall

The BGA244 can save and recall up to 20 different setups. Each setup contains all parameters that can be set on the BGA244; including the instrument mode, gas selection, display setup and I/O parameters. Stored setups can be given an alpha numeric name, making it easy to identify details about each setup. Press [STORE-RECALL] to access the Store Recall menu.

If a setup is over written or erased, it cannot be retrieved.

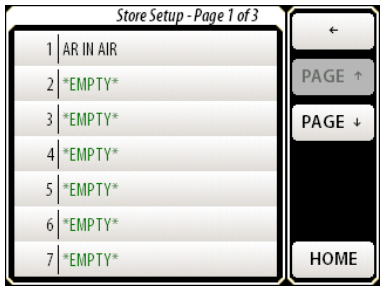
There are two setups that cannot be changed or deleted. The *Default Setup* configures the BGA244 as described in the Default Setup Table (page 66). The *Factory Setup* places the BGA244 into the same configuration as when it left the factory. See *Factory Setup* (page 69) for details.

> **Note:** Setups are stored into Flash memory with a life time of about 100,000 erase cycles. Don't continuously store settings especially over the computer interfaces to avoid wearing out the memory.

If storing, recalling or erasing a setup fails once, try a second time. If it fails repeatedly, try a different location. This failure indicates a problem with the storage memory. See *Troubleshooting* (page 173) for more information.

Setup List

Pressing [STORE], [RECALL] or [ERASE] will open the Stored Setup list. This list contains the Default Setup and 20 available setup locations and their names. Use [Page ↑] and [Page ↓] to navigate the entire list. Filled setup locations are named; if no alpha numeric name was entered, the name "Setup x" is used ("x" is the setup location). Empty setups are denoted by "*Empty*".



Store

Press [STORE] to open the Setup list.

Press the desired setup. If the selected location is currently filled, a prompt will appear asking if you want to continue. You cannot store a setup to Location 0 (Default Setup)

Enter the setup name using the alpha-numeric keypad. If you selected a currently filled location a prompt will appear asking if you want to change the setup name.

A confirmation prompt will appear containing the setup name and if the setup was stored successfully.

When entering a name for a setup, try to be descriptive. For example, “ARGON IN OXYGEN, 1%” could indicate Gas 1 = Argon, Gas 2 = Oxygen, full scale output = 1%. This makes it easier to identify each setup.

Recall

Press [RECALL] to open the Setup list. Note that Setup 0 is the Default setup.

Press the desired setup.

A confirmation prompt will appear containing the setup name and if the setup was recalled successfully.

Erase

Press [ERASE] to open the Setup list.

Press the desired setup. A prompt will appear asking if you want to erase the selected setup.

A confirmation prompt will appear if the setup was successfully erased.

Default Setup

TABLE 10: ACTIVE PARAMETERS

Parameter	Value
Instrument Mode	Gas Purity Analyzer
Run Mode	Run
Gas Settings	
Purity Gas	Argon
SOS Entry	318.956 m/s
Pressure Settings	
Analysis Pressure	User
User Pressure	0 psi
User Pressure Units	Gauge
Ambient Pressure	14.7 psi
Meter Settings	
Purity Upper Scale	10%
Purity Lower Scale	-10%
Purity Upper Limit	5%
Purity Lower Limit	-5%
Purity Upper Limit Active	Active
Purity Lower Limit Active	Active
Purity Hysteresis	1 %
Purity REL Mode	No REL
Purity REL Value	0 %
Event Settings *	
Event 1 Configuration	Nothing Selected
Event 2 Configuration	Nothing Selected
Event 1 Force	No Force
Event 2 Force	No Force
Temperature Meter Settings	
Temperature Upper Scale	50 °C
Temperature Lower Scale	10 °C
Temperature Upper Limit	45 °C
Temperature Lower Limit	25 °C
Temperature Upper Limit Active	Active
Temperature Lower Limit Active	Active
Temperature Hysteresis	1 °C
Display Settings	
Display Orientation	0 degrees
Display Backlight	10
Display Key Click	On
Units Settings	
Ratio Units	%
Speed Units	m/s
Temperature Units	°C
Pressure Units	psi
Measurement Settings	
Average Mode	On
# Averages	10
Dispersion Compensation	On

Parameter	Value
Amplitude	Auto
BGA Concentration	Mole Fraction
Heater Settings *	
Block Heater Mode	Off
Heater Temperature	40 °C
Max Current	2.0 A
Degas Heater	Off
Computer I/O Settings	
RS-232	Enabled
Baud Rate	9600
RS-422 *	Enabled
Baud Rate *	9600
Analog Inputs Settings *	
Analog Input 1	Enabled
Analog Input 1 Type	Voltage
Analog Input 1 Loop Power Voltage	12 V
Analog Input 2	Enabled
Analog Input 2 Type	Voltage
Analog Input 2 Loop Power Voltage	12 V
Analog Output 1 Settings *	
Analog Output 1	Enabled
Analog Output 1 Type	0 – 10 V
Analog Input 1 Linked to	USER
Analog Output 1 User Value	0 V
Analog Output 2 Settings *	
Analog Output 2	Enabled
Analog Output 2 Type	0 – 10 V
Analog Output 2 Linked to	USER
Analog Output 2 User Value	0 V
Parameter	Value
Measure Output Settings *	
Measure Output	Enabled
Measure Output Type	0 – 10 V
Measure Output Linked to	Purity Deviation
Measure Out Purity Scale Min	-10 %
Measure Out Purity Scale Max	+10 %
Misc. Settings	
Alerts	All Enabled
Use Password	Off
Password	0000

* Settings marked with * are only operational with the Industrial Control Option (Option 1) and 24V connected to the unit. They can be configured if Option 1 is installed even if 24V is not present.

TABLE 11: INACTIVE PARAMETERS

Parameter	Value
Binary Gas Analyzer Settings	
BGA Gas 1	Argon
BGA Gas 2	Air
BGA Upper Scale	105%
BGA Lower Scale	95%
BGA Upper Limit	102%
BGA Lower Limit	98%
BGA Upper Limit Active	Active
BGA Lower Limit Active	Active
BGA Hysteresis	1 %
BGA REL Mode	No REL
BGA REL Value	0 %
Physical Measurement Settings	
Physical Gas	Argon
Physical Upper Limit	1000 m/s
Physical Lower Limit	0 m/s
Purity Upper Limit Active	Inactive
Purity Lower Limit Active	Inactive
Purity Hysteresis	1 m/s
Pressure Meter 1 Settings *	
Use Analog In 1 as Pressure Gauge 1	Inactive
Gauge 1 Units	Gauge
Gauge 1 Min	0 psi
Gauge 1 Max	150 psi
Gauge 1 Upper Scale	150 psi
Gauge 1 Lower Scale	0 psi
Gauge 1 Upper Limit	100 psi
Gauge 1 Lower Limit	10 psi
Gauge 1 Upper Limit Active	Inactive
Gauge 1 Lower Limit Active	Inactive
Gauge 1 Hysteresis	1 psi
Pressure Meter 2 Settings *	
Use Analog In 2 as Pressure Gauge 2	Inactive
Gauge 2 Units	Gauge
Gauge 2 Min	0 psi
Gauge 2 Max	150 psi
Gauge 2 Upper Scale	150 psi
Gauge 2 Lower Scale	0 psi
Gauge 2 Upper Limit	100 psi
Gauge 2 Lower Limit	10 psi
Gauge 2 Upper Limit Active	Inactive
Gauge 2 Lower Limit Active	Inactive
Gauge 2 Hysteresis	1 psi
Analog Output 1 Settings *	
Analog Output 1 Speed Scale Min	0 m/s
Analog Output 1 Speed Scale Max	2000 m/s
Analog Output 1 Speed NTP Scale Min	0 m/s
Analog Output 1 Speed NTP Scale Max	2000 m/s
Analog Output 1 Temp Scale Min	0 °C

Parameter	Value
Analog Output 1 Temp Scale Max	50 °C
Analog Output 1 Press 1 Scale Min	0 psi
Analog Output 1 Press 1 Scale Max	150 psi
Analog Output 1 Press 2 Scale Min	0 psi
Analog Output 2 Settings *	
Analog Output 2 Speed Scale Min	0 m/s
Analog Output 2 Speed Scale Max	2000 m/s
Analog Output 2 Speed NTP Scale Min	0 m/s
Analog Output 2 Speed NTP Scale Max	2000 m/s
Analog Output 2 Temp Scale Min	0 °C
Analog Output 2 Temp Scale Max	50 °C
Analog Output 2 Press 1 Scale Min	0 psi
Analog Output 2 Press 1 Scale Max	150 psi
Analog Output 2 Press 2 Scale Min	0 psi
Measure Out Settings *	
Measure Output Linked to	Gas Concentration 1
Measure Out BGA Scale Min	0 %
Measure Out BGA Scale Max	+100 %
Measure Out Physical Scale Min	200 m/s
Measure Out Physical Scale Max	2000 m/s

* Settings marked with * are only operational with the Industrial Control Option (Option 1) and 24V connected to the unit. They can be configured if Option 1 is installed even if 24V is not present.

Factory Setup

Caution: Loading the Factory Settings will erase all stored setups as well as the User Gas Table. This procedure cannot be "Un-done" so be certain that you want to do it before starting.

The Factory Setup is used to set the BGA244 to its initial condition, with no user defined setups or User Gas Table. It consists of the following steps:

- Recall 0 (Default Setup)
- Erase Stored Settings 1-20
- Delete the User Gas Table

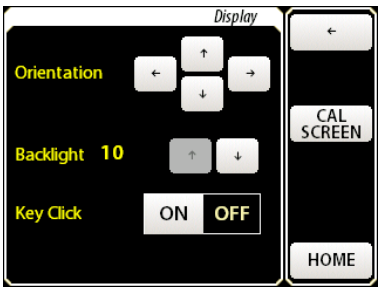
Press [FACTORY] to load the factory setup. A confirmation prompt will appear if the factory setup was recalled successfully.

Control Panel

The remainder of the controls and measurements in the BGA244 are accessed through the Control Panel. Press [CONTROL PANEL] to access this menu. Use [PAGE ↑] or [PAGE ↓] to navigate the different functions. Press the Function name to enter that page. The Control Panel menu includes:

Display
Units
Measurement
Status
Heater
Computer IO
Analog IO
Faults
Alerts
Message Log
Self Test
Password
About

Display



Since the BGA244 can be mounted in any orientation, the display needs to be rotated for proper viewing. The back light intensity and key clicks can be set. In addition, the screen coordinates can be calibrated. Press [DISPLAY] to access the Display controls.

Display Orientation

The display can be viewed from 4 different orientations, indicated by the four arrow buttons. Press whichever arrow points up to rotate the display where that direction is up.

Backlight Intensity

The display backlight intensity can be varied from full on (10) to nearly off (1). In high brightness conditions the backlight should always be set to full intensity.

Reducing the backlight intensity minimize the power supply current. Setting it to the minimum reduces the current by nearly 100 mA. This is really only useful when operating the BGA244 off of poor quality USB power and isn't commonly done.

Press [↑] to increase the back light intensity. Press [↓] to decrease the back light intensity.

Key Click

The key click can be turned on and off. They should normally be left on to provide feedback that a key was pressed but can be turned off if necessary.

Press Key Click [ON|OFF] to toggle the Key Click sound on and off. When turning the key click off you will hear the final click as the button is pressed. When turning it on there is a longer beep.

Screen Calibration

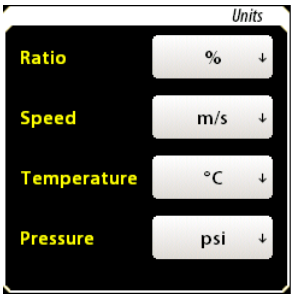
The resistive touch screen used in the BGA244 can drift over time. This can cause the active location of buttons and controls to not align correctly with the graphics. This drift is normally quite slow, but large temperature changes can accelerate it. If the key push location isn't aligned well with the screen graphics, use the following procedure to calibrate the screen.

- Press [CAL SCREEN] to begin the screen calibration process.
- Touch the center of each crosshair as prompted.
- When the calibration is complete the BGA244 will return to the Home page.

You can also enter the screen calibration routine by pressing a finger to the screen when power is applied. Hold your finger down until the message "Release Screen to start Screen Calibration" appears, then follow the instructions to complete the routine.

Units

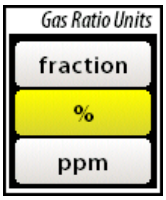
The BGA244 displays several different types of measurements including ratios, speeds of sound, temperatures and pressures. Each measurement can have one of several different units.



Ratio

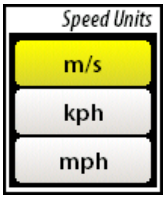
Ratio units are used in measurements that are ratios of one quantity to another. They are used for gas concentration (Binary Gas Analyzer) and ratio of speeds of sound (Gas Purity Analyzer).

Allowable units are: fraction (0 to ±1.0), % (percent) and ppm (part-per-million). Press <Ratio ↓> to open the selection list. The currently selected unit will be highlighted in yellow. Press the desired value to select it.



Speed

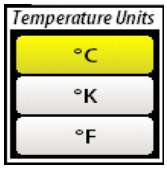
Speed units are used for speeds of sound measurements. They are primarily used on the Physical Measurements page.



Allowable units are: m/s, kph (kilometers/hour) and mph (miles/hour). Press <Speed ↓> to open the selection list. The currently selected unit will be highlighted in yellow. Press the desired value to select it.

Temperature

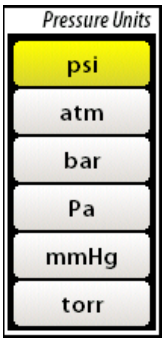
Temperature units are used for gas temperature readings and heater settings.



Allowable units are: °C, °K and °F. Press <Temperature ↓> to open the selection list. The currently selected unit will be highlighted in yellow. Press the desired value to select it.

Pressure

Pressure units are used for gas pressure readings.

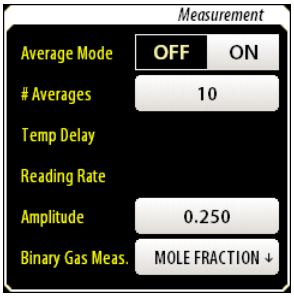


Allowable units are: psi, atm, bar, Pa, mm/Hg and torr. Press <Pressure ↓> to open the selection list. The currently selected unit will be highlighted in yellow. Press the desired value to select it.

Note that for pressure setting and entry the pressure units are defined as either absolute units (relative to vacuum) or gauge units (relative to atmospheric pressure). This selection is made on the Configure Pressure Gauge or Configure User Pressure pages. See the *Pressure* section earlier in the chapter for more information.

Measurement

The default configuration for the BGA244 is optimized for a wide range of gases, pressures, temperatures, flow rates and other environmental conditions. However there are circumstances when measurement and analysis can be tuned for better performance. Refer to *Chapter 4: Application Guide* for conditions when optimizing these parameters may be useful.



Averaging

Averaging successive measurements can improve accuracy and repeatability of the measurements by reducing interfering signals and noise. See *Using Averaging* (page 103) for more information. The BGA244 takes a measurement every 228 ms. This is quite a bit faster than most processes change, so a moderate number of averages doesn't create a noticeable delay.

The averaged output is continuously calculated, producing a new averaged measurement for every input measurement following the formula:

$$Average_N = [1/N * Measure_N] + [(1 – 1/N) * Average_{N-1}]$$

For signals without large transients, the averaged value settles to within 1% of its final value in about 5 * N measurements or N * 1.14 seconds. For the default value of 10 averages the averaged output settles in about 11.4 seconds.

Large transients may persist in averaged measurements for a long time. They may take several times as long to decay as the settling time. Similarly, any changes in a measurement will only be visible if they last for a sufficient number of samples.

Press [OFF|ON] to toggle averaging on and off. Enter the number of averages between 2 and 100.

Relaxation Correction

Gases take different amount of times to reach thermodynamic equilibrium between their translational, rotational and vibrational degrees of freedom. If that amount of time is comparable with an acoustic cycle of the resonant mode, a small correction factor is applied to the applied to the heat capacity used to compute the speed of sound. This phenomena is most prevalent in pure gases, with CO2 being the most egregious example. However if even a small amount of a second gas is added, the effect largely vanishes. See *Relaxation Effects* (page 92) for a list of gases that exhibit this.

Relaxation Correction should be used if you are measuring relatively pure gases that are highly dispersive. It should be turned off if you are measuring mixtures. Press [OFF|ON] to toggle relaxation correction on and off.

Amplitude

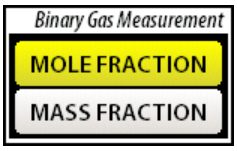
The amplitude of the speaker signal is optimized for the best signal to noise ratio of measurements within the acoustic cell. In rare cases this amplitude may cause the acoustic signal to over or under load the preamplifier. The BGA244 detects this and adjusts the amplitude accordingly. When this occurs there is a brief period when measurements are invalid until the acoustic signal settles to the new value, reported by an Invalid screen message.

Ordinarily the amplitude should be left in the default auto amplitude setting. If there are numerous Invalid messages due to amplitude changes, it may be helpful to set the amplitude to a lower fixed value. View the message log to see if an Invalid message is due to an amplitude change.

Press <Amplitude ↓> to open the selection list. The allowed selections are: auto, ½ and ¼ full scale. The currently selected method will be highlighted in yellow. Press the desired value to select it.

Binary Gas Concentration

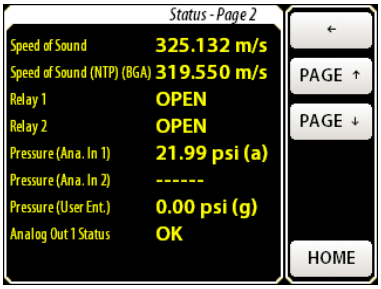
Binary gas measurements can be reported in one of two formats: mole fraction and mass fraction. See *Converting Mole Fraction* (page 106) for a detailed description of the relationship between them.



Press <Binary Gas Measurement ↓> to open the selection list.
The currently selected method will be highlighted in yellow. Press the desired value to select it.

Status

This page lists the present value of most of the parameters measured by the BGA244. If a parameter isn't currently configured in the BGA244 or is for an uninstalled option it will be dashed out (-----). Use [PAGE ↑] and [PAGE ↓] to navigate the list of measured parameters.



List of Monitored Parameters

Speed of Sound (Measured)
Speed of Sound (NTP)
Gas Temperature
Analysis Pressure
Block Temperature
PCB Temperature
Heater Power
USB Voltage
External Voltage
Analog In 1 Value
Analog In 2 Value
Measure Out Value
Analog Out 1 Value
Analog Out 2 Value

Heater

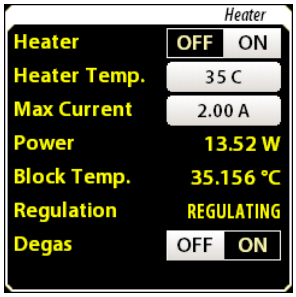
The BGA244 heaters serve several purposes. They are used to stabilize the measured gas temperature, to prevent condensation and to help with high purity bake out. There are two separate heaters: the Block Heater and the Degas Heater. Information on settling time and specific uses of the heaters is available in the *Chapter 4: Applications Guide.*

Note: The Gas temperature will usually not match the block temperature due to heat flow in the gas and acoustic cell. In addition, the Block and Set temperatures may differ by a few degrees. This is normal for the BGA244.

The Heaters can only be used if Option 1 (Industrial Control Option) is installed and an external +24 VDC power supply is connected to the BGA244. The maximum Block Heater current drawn from the external supply can be set between 50 mA and 2.2 A. The current draw of the Degas Heater is fixed at about 140 mA.

The Block Heater can be used during either analysis or bake out. The Degas Heater cannot be used during analysis. If the Degas Heater is active, a “DEGAS ON” message is displayed on the Home page. See *Screen Messages* (page 49) for more information.

Block Heater



The Block Heater can apply over 50W of power to heat the cell temperature to as high as 70 °C. The Block Heater is over-temperature and over-current protected.

The Block Heater uses a temperature servo to maintain the temperature of the cell to the set point. It will hold the temperature stable assuming the following conditions are true.

- The Block Heater temperature set point is at least 3 degrees above the highest ambient temperature.
- The Maximum Heater Current is large enough so the heater can raise the cell temperature up to the Block Heater set temperature for the lowest ambient temperature.

Press Heater [ON|OFF] to toggle the Block Heater on and off. Enter the Heater Temperature between 0 and 70 °C. Enter the Maximum Current between 0.05 and 2.2A.

The endplate temperature and power being applied to the BGA244 is reported. The Regulating Indicator shows when the temperature servo is actively regulating the temperature.

If the cell temperature comes out of regulation, try the following:

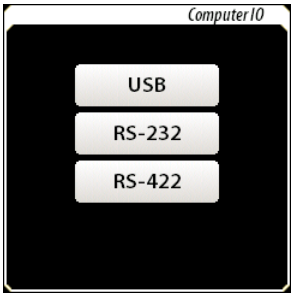
- If the cell temperature is above the set temperature, increase the set temperature. If the maximum set temperature is exceeded (70 °C), it may be necessary to either allow the BGA244 to operate without temperature regulation or to reduce the temperature of the gas or the environment. Remember to not exceed the maximum operating temperature (70 °C).
- If the cell temperature goes below the set temperature, increase the maximum heater current. If the maximum allowable heater current cannot raise the temperature to the required temperature, the operating environment temperature needs to be increased. A simple way to do this is to add insulation around the BGA244.

Degas Heater

The Degas Heater can only be used during system bake out. It is normally used in conjunction with the Block Heater to bake out the BGA244 cell for use high purity systems. The Degas heaters operate by heating the speaker and microphone Kapton membranes directly. They draw about 70 mA and provide about 0.25 W of heat. The BGA244 cannot make gas measurements while the Degas Heater is active. This is indicated on the Home Page by the “DEGAS ON” screen message.

Press Degas [ON|OFF] to toggle the Degas Heater on and off.

Computer IO

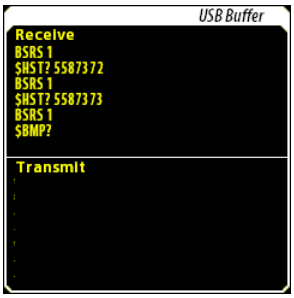


The BGA244 has three separate computer interfaces that can control and monitor all functions. Details on controlling the BGA244 over the computer interfaces are described in *Chapter 6: Remote Programming*.

The USB and RS-232 interfaces are installed on all BGA244s. The RS422 is only available if the Industrial Control Interface (Option 1) is installed and requires that an external +24V power supply is connected to operate.

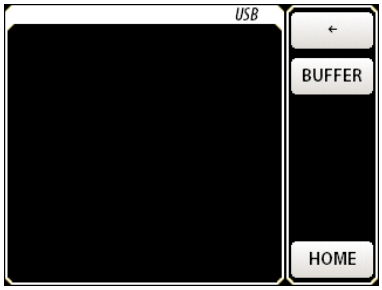
The RS-232 and RS-422 interfaces can be enabled and disabled and have settable baud rates from 2400 to 115.2k baud. The USB has no enable or configuration functions. Press [USB], [RS-232] or [RS-422] to access that interfaces page.

Receive and Transmit Buffers



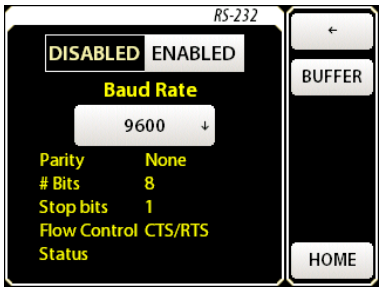
Each interface has its own set of receive and transmit buffers that show the most recent commands and responses over that interface. They can be helpful when debugging communication problems. Press the [BUFFER] key on the interface page of interest to view.

USB



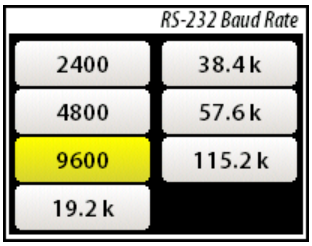
Nothing can be set for the USB interface. The only control on the USB page is the [BUFFER] key. Press it to view the transmit and receive buffers.

RS-232



Press [DISABLE|ENABLE] to enable or disable the RS-232 interface. Press [BUFFER] to view the transmit and receive buffers.

Press <Baud Rate ↓> to open the selection list. The currently selected rate will be highlighted in yellow. Press the desired value to select it. Most of the remaining parameters are read only.



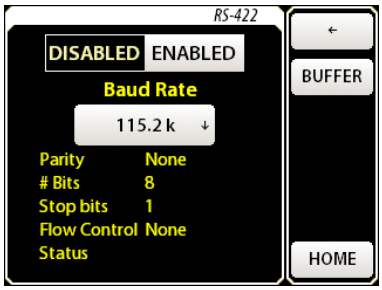
Parity:	None
# of Bits:	8
Stop Bits:	1
Flow Control:	CTS/RTS

The following RS-232 communication problems are reported in the *Message Log* (page 86).

- Parity Error
- Break
- Frame Error

RS-422

The RS-422 Interface page is similar to the RS-232 page. [ENABLE|DISABLE], <Baud Rate↓> and [BUFFER] all operate in the same manner. There is no Flow Control for the RS-422.

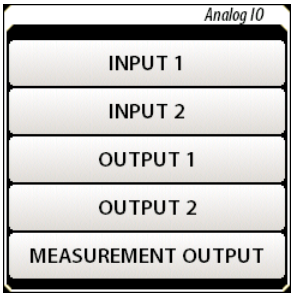


Note that the Industrial Control Option (Option 1) must be installed and 24V must be present for the RS-422 interface to be operational.

The following RS-422 communication problems are reported in the *Message Log* (page 86).

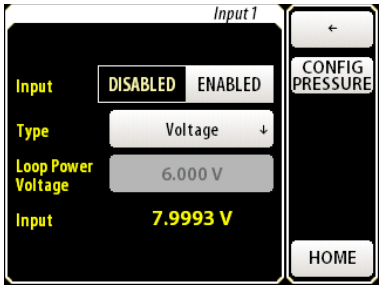
- Parity Error
- Break
- Frame Error

Analog IO



The BGA244 has two analog inputs and three analog outputs that can be used to interface to external devices, sensors or meters. Refer to *Analog I/O* (page 26) for details on connecting the analog inputs and outputs to external circuits. See the *Specifications* for details on the analog inputs and outputs performance. The Analog Inputs and Outputs are only available if Industrial Control Interface (Option 1) is installed and will only operate if an external +24V power supply is connected.

Analog Inputs

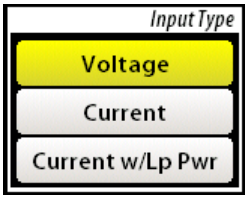


The two Analog Inputs (INPUT 1 and INPUT 2) can each be set to measure either voltage, current or current with a loop power voltage source. The measured voltage or current can be viewed on the BGA244 or read over one of the computer interfaces. Press [INPUT 1] or [INPUT 2] to go to their configuration page.

Analog inputs can be used as either general purpose inputs, or together with a transducer as a pressure meter. If an analog input is configured as a pressure meter it may not be used for general purpose measurements. In either case the input must be configured properly for the desired measurement. The Input reading displayed on this page is in V or mA regardless if the analog input is used as a pressure meter.

[CONFIG PRESSURE] takes you to the Configure Pressure Gauge page as described in *Pressure* (page 61) earlier in this chapter. To set an input to general purpose, uncheck "Use as Pressure Gauge" on the Configure Pressure Gauge page.

Press [ENABLE|DISABLE] to enable or disable the analog input. Press <Type ↓> to open the selection list. The currently selected type will be highlighted in yellow. Press the desired value to select it.



The Loop Power Voltage can be entered if Current w/Loop Power is selected. This can vary from 6 and 19 V. See *Analog Input* (page 27) for details on devices that can use loop power.

There are several alerts that can occur for the Analog Inputs. They appear as red text at the bottom of the Analog Input page as well as on the Alert page. These normally indicate a problem with the device connected to the Analog Input or wiring, rather than the input itself.

Name	Valid for	Indicates
Undervoltage	Voltage	Input < 0 V
Overvoltage	Voltage	Input > 10.2 V
Undercurrent	Current	Input < 4 mA
Overcurrent[1]	Current	Input > 20 mA
Loop Power[2]	Current w/ Loop Power	Loop Power current is > xx mA

[1] Note that the Loop Power Alert is shared between Input 1 & 2. All other alerts are separate for Input 1 & Input 2. This alert does not self clear and must be cleared manually.

[2] The Input 1/2 Overcurrent condition switches out the current sense resistor when the input current exceeds 26 mA. It will automatically switch the current sense resistor back in when the input ***voltage*** drops below 5.8 V. In some cases it may be necessary to manually reset an overcurrent fault due to the behavior of the external circuitry.

All of these Alerts except Loop Power self clear if the condition that caused them goes away. See the Message Log for a history of transient events. See *Alert* (page 84) for details on alert behavior.

Analog Outputs

There are three separate Analog Outputs that can be configured as 0 – 5 V, 0 – 10 V or 4 – 20 mA outputs. Measure Out is always linked to the measured value of the selected instrument mode. Outputs 1 and 2 can be linked to one of several different measured quantities or set explicitly by the user. Outputs linked to a measured quantity can be scaled to match a specific range using global units. For example, Measure Out can be scaled so a 0 to 1% gas concentration corresponds to a 0 to 10 V output to interface to an external device.

Use the Scale Min and Scale Max values to scale the analog output relative to the linked parameter. Scale Min is the value for the minimum analog output (0 V or 4 mA). Scale Max is the value for the maximum analog output (5 V, 10 V or 20 mA). Scale Min and Max are always set in the selected Global Unit for that parameter.

> **Example:** In Binary Gas Analyzer mode, the Measurement Output is always linked to the Gas Concentration ratio (%, ppm or fraction). So Scale Min and Scale Max are entered as ratios.
>
> **Example:** Analog Output 1 can be linked to the gas temperature (°C, °K or °F). In this case, Scale Min and Scale Max are entered as temperatures.

If the values of the linked parameters exceed the Scale Min or Scale Max values, the Analog Outputs will pin to their respective minimum or maximum values.

If the full scale ranges of the external device and the analog output don't match, you can still calculate what the measured output would be for the minimum and maximum analog output values.

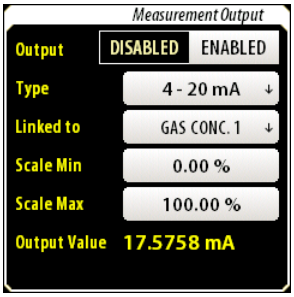
Example: You need a 1 to 8 V output for a Gas Concentration of 10% to 20%.
Use the 0 – 10 V setting for the Measure Output.
7V corresponds to 10%, so 1V ~ 1.43%
Scale Min (0V) = 10% - 1.43% = 8.57%
Scale Max (10) = 20% + (2 * 1.43%) = 22.86%

There are two alerts that can occur for the Analog Outputs. They appear as red text at the bottom of each Analog Output page and on the Alert page. These normally indicate a problem with whatever is connected to the Analog Output rather than a problem with the output itself.

- IOut Alert indicates that the current output can't output the required current. This usually indicates a break in the 4-20 mA current loop or an overly large series resistor.
- Temperature Alert indicates the output driver has overheated and is in thermal limit. This usually indicates that the output is shorted.

These alerts self clear if the condition that caused them goes away. See the Message Log for a history of transient events. See *Alerts* (page 84) later in this chapter for details on alert behavior.

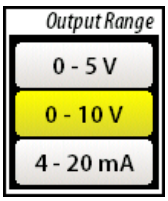
Measure Output



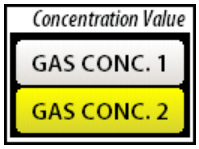
Measure Out is always linked to the measured parameter set by the Instrument Mode as follows:

- Binary Gas Analyzer: Gas Concentration Ratio
- Gas Purity Analyzer: Speeds of Sound Ratio
- Physical Measurements: Normalized speed of sound

The present Output Value (voltage or current) is displayed just below Scale Max.



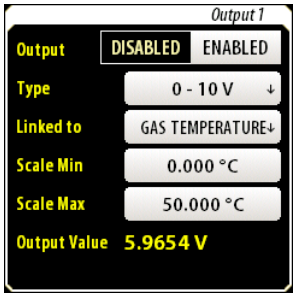
Press [ENABLE|DISABLE] to enable or disable the output. Press <Type ↓> to open the selection list. The currently selected type will be highlighted in yellow. Press the desired value to select it. Enter the Scale Min and Scale Max values.



Select Gas Concentration 1 or 2 using <Linked to ↓>. Normally these values are identical. However there are rare cases where there are two possible solutions for a given speed of sound. In this case Gas Concentration 1 is always the lower concentration and Gas Concentration 2 the higher one. Refer to *Gases* (page 91) for details.

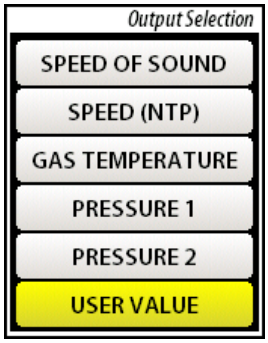
Enter Scale Min and Scale Max to scale the Measure Output relative to the value of the measured parameter. They are in ratio units for the Binary Gas and Gas Purity, or in speed units for Physical Measurements.

Output 1 and Output 2



Analog Output 1 and 2 can be linked to several different parameters or be explicitly set from the GUI or computer interface as a User value. Analog Output 1 and Output 2 scale in the same manner as the Measure Output if linked to a measured parameter. Possible linked parameters include:

- Measured Speed of Sound
- Normalized Speed of Sound
- Gas Temperature
- Pressure Meter 1 or 2 (if configured)
- User: Set thru the GUI or over the computer interfaces.



Press [ENABLE|DISABLE] to enable or disable the output. Press <Type↓> to open the selection list. The currently selected type will be highlighted in yellow. Press the desired value to select it.

Press <Linked to↓> to open the selection list. The currently selected type will be highlighted in yellow. Press the desired value to select it.

If User Value is selected, a User Setting entry box will appear below “Linked to”. Enter a value within the full scale range for that output type. Otherwise enter the Scale Min and Scale Max values for the linked parameter.

The present Output Value (voltage or current) is displayed just below Scale Max or User Setting.

Faults

The BGA244 monitors several critical parameters. An Instrument Fault is generated if any of these goes out of range. These faults indicate that something serious is wrong with either the BGA244 or the power supplies connected to it. These faults are listed on the Faults page and can be read over the computer interface (see Remote Programming, page 136). See *Troubleshooting* (page 173*)* for further details.

Faults will self-clear if the problem causing them goes away. To view transient events go to the Message Log. There are three main types of faults: External Power Supply Faults, General Faults and Self Test Faults.

If any fault occurs, the red [System Fault] button appears on the Home page and the [Home] button turns red on all pages. Pressing [System Fault] takes you to the Faults page.

If an External Power Supply occurs, the POWER LED will flash at ~4 Hz. If a General or Self Test Fault occurs, the ERROR LED will stay on continuously.

External Power Supply Faults

If the BGA244's power supply input voltages fall outside the specified range, an external power supply fault will be generated. The +5V USB power supply is monitored only when the unit is powered over USB (no +24V). Otherwise the External +24V power supply is monitored. The following faults are displayed on the Faults page and are indicated by the Power LED blinking at about 4 Hz. See *Power* (page 21) for details on power supplies and cabling.

> **Note:** There must be a minimum voltage (~ 3.3 V for USB, 18 V for the External +24) for the BGA244 to control the display or LEDs.

TABLE 12: EXTERNAL POWER SUPPLY FAULTS

Fault Name	Meaning
USB Undervoltage	External USB Supply < 4.45V
USB Overvoltage	External USB Supply > 5.50V
24V Overvoltage	External 24 Supply > 28V

USB Undervoltage Fault: This is usually caused by a USB port that cannot provide sufficient current or a high resistance USB cable.

USB Overvoltage Fault: This fault may be caused by a faulty USB supply.

24V Overvoltage Fault: This fault indicates a faulty or improper power supply. Confirm that the 24V Power Supply is appropriately rated.

General System Faults

General System Faults are critical errors that occur while the BGA244 is operating. These faults indicate a problem with the internal circuitry or a serious temperature problem. The following faults are displayed on the Faults page and are indicated by the ERROR LED staying on continuously.

TABLE 13: SYSTEM FAULTS

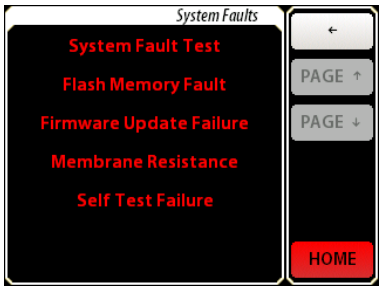
Fault Name	Meaning
Under Temperature	Cell Temperature reads < -20 °C
Over Temperature	Cell Temperature reads > 80 °C
Flash Fault	Fatal Error in Flash Memory
Firmware	Error in Firmware Update
Heater Fault	Block Temperature reads > 90 °C
1.4V Under Voltage	Internal 1.4V Supply too low
1.4V Over Voltage	Internal 1.4V Supply too high
3.3V Under Voltage	Internal 3.3V Supply too low
3.3V Over Voltage	Internal 3.3V Supply too high
5V_I Under Voltage	Internal 5V Supply too low
5V_I Over Voltage	Internal 5V Supply too high

Self Test Fault

The BGA244 runs a series of Self Tests at power on, or when requested from the Self Test page or the *TST command over the computer interfaces. A Self Test fault is generated if any of the Self Tests fail. See *Self Test* (page 86) for more details.

Faults Page

The Faults page provides a list of all currently active Faults. Use [PAGE ↑] and [PAGE ↓] to navigate the list of Faults. If the faulting condition goes away, the Fault will self-clear and be removed from the list. To view transient events go to the Message Log.



Alerts

Alerts are warnings of non-critical conditions. These may be problems with the BGA244 or with external devices or wiring.

If an alert occurs, the yellow [Alert] button appears on the Home page and the [Home] button turns yellow on all pages. Pressing [Alert] takes you to the Alerts page. Each Alert can be cleared or disabled using its Alert Action Window.

Most Alerts will self-clear if the problem causing them goes away. Transient events can be viewed on the Message Log. There are three main types of alerts: Analog I/O Alerts, Temperature Alerts and General Alerts.

Analog I/O Alerts

There are a number of alerts that can occur for the Analog Inputs and Outputs. These normally indicate a problem with whatever is connected to the Analog Input or Output and not a problem with the BGA244. All Alerts except the Input 1/2 Loop Overcurrent will self clear when the condition causing them is eliminated. See *Analog I/O* (page 78) for details on the specific alerts.

TABLE 14: ANALOG I/O ALERTS

Alert Name	Meaning
Input 1 Undervoltage	Input 1 < -0.1 V (V In only)
Input 1 Overvoltage	Input 1 > 10.2 V (V In only)
Input 1 Undercurrent	Input 1 < 3.5 mA (I in only)
Input 1 Overcurrent	Input 1 > 26 mA (I in only) *
Input 2 Undervoltage	Input 2 < -0.1 V (V In only)
Input 2 Overvoltage	Input 2 > 10.2 V (V In only)
Input 2 Undercurrent	Input 2 < 3.5 mA (I in only)
Input 2 Overcurrent	Input 2 > 26 mA (I in only) *
Input 1/2 Loop Overcurrent	Input 1 or 2 Loop Power current is > xx mA
Measure Output Current	Measure Out cannot output the required current
Measure Out Temp	Measure Out Over Temperature
Output 1 Current	Output 1 cannot output the required current
Output 1 Temp	Output 1 Over Temperature
Output 1 Current	Output 1 cannot output the required current
Output 1 Temp	Output 1 Over Temperature

Temperature Alerts

There are several alerts that indicate that the cell temperature is out of range or there are discrepancies between the two temperature sensors.

TABLE 15: TEMPERATURE ALERTS

Alert Name	Meaning
Under Temperature	Cell Temperature < 0 °C
Over Temperature	Cell Temperature > 70 °C
Temperature Mismatch	Mismatch between temperature sensors > 5 °C

General Alerts

These are alerts that indicate non optimal power supply levels or that the heater isn't regulating properly. The +5V USB power supply is monitored only when the unit is powered over USB (no +24V). Otherwise the External +24V power supply is monitored.

TABLE 16: GENERAL ALERTS

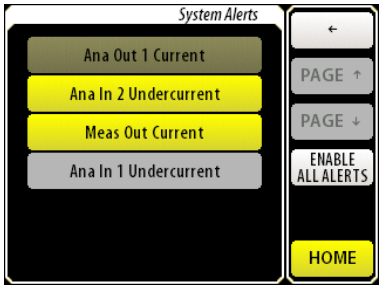
Alert Name	Meaning
USB Undervoltage	External USB Supply < 4.6 V
USB Overvoltage	External USB Supply > 5.3 V
24V Undervoltage	External 24 Supply < 22 V
24V Overvoltage	External 24 Supply > 26 V
Heater Not Regulating	The Cell Heater is not regulating

The Under and Over Voltage Alerts indicate that the power supply input voltages are marginal. This may indicate a problem with the power supply or cabling. See *Power* (page 21*)* for details on power supplies and cabling.

Heater Not Regulating indicates that the heater servo is set to its minimum or maximum values and is not correctly regulating the cell temperature. It is only active when the heaters are on. See *Heater* (page 75) for more details.

Alerts page

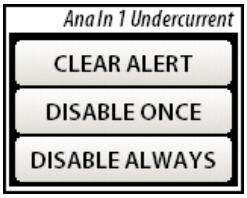
Each Alert appears as a separate multipurpose button on the Alerts page. Use [PAGE ↑] and [PAGE ↓] to navigate the list of Alerts.



Most Alerts self clear and vanish when the problem causing them goes away. Pressing a particular [ALERT] button will take you to its Alert Action Window that allows you to control the appearance and behavior of the alerts. Note that all alert actions are lost if the power is cycled.

Alert Actions

Press [CLEAR ALERT] to clear a currently active alert. This is only useful for alerts that are not self clearing. Other Alerts will immediately re-assert themselves after being cleared, since they are still active.



Press [DISABLE ONCE] to ignore a currently active alert. This will cause the alert to be ignored and clear the alert indicators (assuming this is the only active alert). The Alert button will turn lite grey to indicate its “disabled once” state. If this alert is cleared and later re-asserted, it will revert to the normal “un-ignored” state, with the alert indicators active.

Press [DISABLE ALWAYS] to permanently ignore an active alert. This will cause the alert to be ignored and clear the alert indicators (assuming this is the only active alert). The Alert button will turn dark grey to indicate its “disabled always” state. If this alert is cleared and later re-asserted, it will remain inactive with the Alert added to the list in dark grey until power is cycled.

Press [ENABLE ALL ALERTS] to return all alerts to the active state. This will clear any “Disable Once” or “Disable Always” behavior. Note that power cycling the BGA244 will always enable all alerts.

Message Log

The Message Log is a list of the most recent events that occur in the BGA244. This includes stored and recalled settings, alerts, faults and other messages. The Message Log can be particularly useful in diagnosing transient events that may disappear before they can be properly diagnosed.

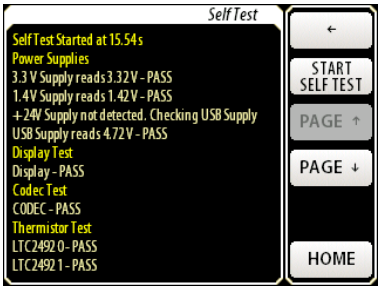
?
Message Log
7.74 - ALERT: Meas Out Current
37.80 - Autosave started
37.80 - Autosave to slot 1
37.82 - Autosave complete to slot 1
56.43 - ALERT: 24V Supply Overvoltage
91.04 - Autosave started
91.05 - Autosave to slot 2
91.08 - Autosave complete to slot 2

Self Test

The Self Test page provides access to the Self Test functions and their results.

Running Self Test

Running Self Test will stop all measurements and can temporarily modify inputs, outputs and relay settings for several seconds. Self Test is the same procedure that is run upon power on or by the computer interface *TST command.



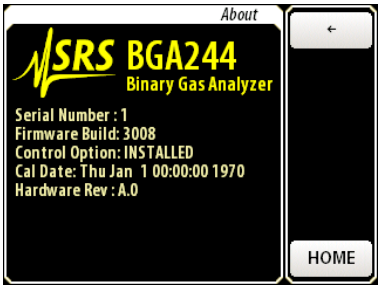
To begin Self Test, press [START SELF TEST]. The tests and their results will be written to the screen. Upon completion, the BGA244 will display “SELF TEST PASS” or “SELF TEST FAIL”. Use [PAGE↑] and [PAGE↓] to navigate the list of tests. If Self Test fails it will be listed on the Faults page.

In a properly operating unit Self Tests should pass every time. See *Troubleshooting* (page 173) for information about Self Test failures.

TABLE 17: SELF TESTS

Test Name	Description
3.3 V Supply	Internal 3.3 V Power Supply is within range
1.4 V Supply	Internal 1.4 V Power Supply is within range
4.5 V Supply	Internal 4.5 V Power Supply is within range Not performed on Rev C hardware
USB Supply	External USB Power Supply is within range Not performed if Option 1 is installed and +24V is present
24 V Supply	External 24 V Power Supply is within range Performed if Option 1 is installed and +24V is present
5 V Industrial Supply	Internal 5 V Power Supply is within range Performed if Option 1 is installed and +24V is present
Display	Display is detected Not performed if Option 2 is installed
CODEC	CODEC is detected
ADC 0	ADC 0 is detected
ADC 1	ADC 1 is detected
Thermistor 1	Thermistor 1 resistance is within range
Thermistor 2	Thermistor 2 resistance is within range
Membrane 1	Membrane 1 resistance is within range
Membrane 2	Membrane 2 resistance is within range
Magnet 1	Magnet 1 field is within range Not performed on Rev C hardware
Magnet 2	Magnet 2 field is within range Not performed on Rev C hardware
USB	USB is detected. Performed only if USB power or host is connected
DAC 1	Output 1 DAC is detected Performed if Option 1 is installed and +24V is present
DAC 2	Output 2 DAC is detected Performed if Option 1 is installed and +24V is present
DAC x	Measure Out DAC is detected Performed if Option 1 is installed and +24V is present
ADC 3	Measure 1 & 2 ADC is detected Performed if Option 1 is installed and +24V is present

About the BGA244



The About the BGA244 page displays the following information. This is the same information that is displayed on the display during power on.

- Serial Number
- Firmware Version
- Hardware Version
- Installed Options
- Calibration Date

Password

The BGA244 keypad can be locked out with a password enable to keep unauthorized personnel from changing settings on the BGA244. When locked out only the home page can be viewed.

If keypad is locked, a message appears at the top left of the screen. Any key press will open the numeric key pad to allow the user to enter the password. An "Invalid Password" prompt will appear if an incorrect password is entered. After the correct numeric password has been entered, all functions can be accessed. If locking is enabled, the keypad will be re-locked after 30 seconds of no keypad activity.

Press [ON|OFF] to toggle locking on and off. A new password can be entered if locking is on. Enter a 4 digit numeric value to change the password.

If you forget the password, the unit can be reset using Hard Reset function described in the *Hardware Reset* section. This will disable password locking and reset the password to the default value of 0000.

Hardware Reset

The BGA244 has a hardware reset button that can be used if the BGA244 is frozen in an inoperable state. There are two different types of resets with slightly different behaviors.

Use an unbent paper clip or a small screw driver to press the reset button.

Normal Reset

Press the reset button once. Releasing the button forces a Normal Reset. This acts the same as power cycling the BGA244. This is ordinarily used if the BGA244 is in an unknown state and it is difficult to remove power to restart the unit.

Hard Reset

Press the reset button once. Release it, then immediately press and hold the button down for at least 10 seconds to execute a Hard Reset. This acts the same as power cycling the BGA244 and Recalling Setup 0 (Default Setup). This is ordinarily done if something has occurred to put the BGA244 in an inoperable state where loading the Default Setup is impossible, or to reset a forgotten password.

Note that this will replace the current settings of all parameters with the Default Settings. See *Default Setup* (page 66) for details.

User Gases

Gases can be added to the User Gas Table using the BGAMon software. See *User Gases* in *Chapter 5: BGAMon* for details on this procedure.

Updating Firmware

The BGA244 Firmware can be updated by the user using the BGAMon software. See *Updating Firmware* in *Chapter 5: BGAMon* for details on this procedure.

Chapter 4: Application Guide

This section provides information on using the BGA244. It includes details on gases, pressure, operating conditions, measurements, high purity use and adding User gases.

Gases

The BGA244 determines the concentration and purity for a wide variety of gases. It does this by measuring the speed of sound and temperature and then determines the mixture ratio or gas purity using the physical properties of the gases.

The fastest speed of sound that can be measured is ~1400 m/s, the speed of sound for hydrogen (2 amu). The slowest is less than 130 m/s, the speed of sound for SF_6 (146 amu). This range covers nearly all compounds that are gaseous within the operating temperature and pressure range of the BGA244.

Gas Requirements

Gases must be clean and dry. This means they cannot contain any solid or liquid particulates. Gases that contain solid particulates must be filtered before entering the BGA244. It may be necessary to operate the BGA244 at an elevated temperature to ensure there are no liquid particulates in the gas stream.

Gases must be non-condensing and contain no liquid particulates at the temperature and pressure the BGA244 is operating. If a gas is nearing its condensation point the BGA244 will indicate a condensation warning message. See *Condensation* (page 93) for more information.

Gases that can be used

The BGA244 Factory Gas Table contains nearly 500 different gases. These include common industrial gases and a wide range of specialty gases. See *Appendix A: Gas Table* for a list of supported gases.

Gases not included in the Factory Gas Table can be added to the User Gas Table. The minimum data required is the mass and γ (ratio of specific heats) of a gas. Other thermodynamic properties can also be added if available. See *User Gases* (page 113) for more details.

Gases aren't constrained to single species. Gases mixtures or blended gases can also be used. Atmospheric air (N_2, O_2, Ar, CO_2) is included in the Factory Gas Table. Other mixed gases can be added to the User gas table using the procedure described later in this chapter.

Gases that can't be used

SRS does not recommend using explosive, corrosive, flammable or reactive gas mixtures in the BGA244. Avoid gases that react with the wetted materials. See S*pecifications* for a list of wetted materials. In particular avoid:

- Gases that react strongly with copper may damage the acoustic membranes.
- Strong bases (NaOH, KOH) may react with Kapton acoustic transducers
- Gases that contain oils or waxes that can coat the inside of the acoustic cell or Kapton acoustic transducers.

Contact SRS if you have questions about compatibility of a particular gas or mixture with the BGA244.

Unusual Gas Properties

Certain gases have properties that may affect the accuracy of their measurements.

Relaxation Effect

Relaxation (or dispersion) is a non-linear molecular effect that is modeled as a frequency dependence of the heat capacity of a gas. Most gases fully equilibrate (or relax) in less than one cycle of their resonant mode within the acoustic cavity. The few that don't, exhibit a pressure dependent error in the speed of sound in the gas. In most cases this error is only a few 100 ppm. Ordinarily this effect is only observed in nearly pure gases. Adding a small amount of a second gas will cause the mixture to equilibrate more rapidly, reducing the relaxation to less than one cycle of their resonant mode. The amount of the second gas required to achieve this is quite small (<1%). A list of gases that exhibits relaxation is shown in Table 18.

Carbon dioxide (CO_2) is unique in that it has a large relaxation effect at its resonant modes for medium to low gas pressures. This distorts the acoustic signal, leading to large errors or unrecoverable signals. To avoid this effect, the recommended operating pressure for CO_2 is around 18 psia (124 kPa), although the detection threshold is at 13 psia (90 kPa). Again even a small amount of a second gas will allow the mixture to equilibrate much faster, eliminating the effect and allowing the mixture to be measured at lower pressures.

The BGA244 includes data to correct relaxation effects for ratio and purity measurements. This correction can be turned on or off (*Relaxation Correction*, page 73). The correction should be turned on when measuring relatively pure gases and otherwise turned off for mixtures.

> **Note:** Using the relaxation correction will not lower the recommended operating pressure for CO_2. But it will maintain the measurement accuracy for pressures down to 18 psia (124 kPa).

Dimerization

A dimer is a molecule made up of two identical simpler molecules. The analysis techniques used in the BGA244 assumes that the molecules are non-reactive and non-dimerizing.

Condensation

The BGA244 cannot measure gases that are at or near their condensation point. There are two main reasons for this. Actual condensation will interfere with the acoustic cavity making it difficult or impossible to accurately determine the speed of sound. Plus the thermodynamic properties of a gas change radically as it transitions from its gaseous to liquid state. This change makes it impossible to calculate the gas composition and normalized speed of sound. In extreme cases, condensation can actually fill the cell with liquid.

Before actual condensation occurs, pre-condensation can interfere with measurements. During each cycle of the acoustic signal, the pressure within the acoustic chamber increases and decreases slightly. For a gas near condensation, this pressure increase can take the gas into the non-linear region causing large measurement inaccuracies.

Condensation is a function of a particular gas species, its current vapor pressure and temperature. The relative concentration of the gas in a mixture has no effect. Condensation will occur if the temperature is low enough that the vapor pressure of the gas exceeds its saturation value.

Ordinarily gases flowing through the BGA244 aren't near their condensation point. But there are several things that could cause them to condense.

- A reaction may occur at elevated temperatures relative to the BGA244. Condensation may occur when the gas passes into the cooler BGA244.
- The BGA244 can be used to monitor and control the output of a bubbler in a dilution flow. The temperature of the gas bath is adjusted to control the gas concentration. If the BGA244 is operated at a lower temperature than the bath, condensation can occur.
- The BGA244 may be operated at an ambient temperature that is below that of the gas, leading to condensation.

Condensation Warning

The BGA244 contains condensation data on the gases in the Factory Gas Table. By knowing the gas species, concentration, temperature and pressure the BGA244 can detect if the gas is near its condensation point and display a "Condensation Warning" screen message. The BGAMon software also provides information if the conditions and selected gas species are near condensation.

Avoiding Condensation

To avoid condensation, ensure that the saturation point (pressure at which condensation occurs) of the gas species exceeds the partial pressure of the gas within the BGA244. The following techniques can be used to eliminate condensation.

The Block Heaters can be used to raise the cell temperature. The temperature should be high enough so the saturation value of the gas exceeds the partial pressure of the gas. If this temperature is unknown, set the Block Heater to operate at least 3-5 °C above the highest expected gas manifold temperature up to the maximum of 70 °C. Make sure the power supply and Maximum Heater Current are large enough to raise the cell temperature to the set point (typically 0.5 to 2 amps). Refer to *Heater* (page 75) for information on setting the heater.

Water Vapor in Air

Atmospheric air usually contains some water vapor in addition to the usual nitrogen, oxygen, argon and carbon dioxide. This is referred to as humidity. It will affect measurements since water vapor is an additional gas species. Ordinarily mixtures containing water vapor as a third gas should be dried prior to measurement. However in some cases, drying can be avoided by using the REL function to compensate for the third gas.

For this technique to work the amount of water vapor in the "wet" air must be fixed. If it changes, a new REL must be performed. The amount of water vapor must also be low enough to avoid condensation. Note that the condensation point of water (or any liquid) is independent of any other gas species. But it does depend on both temperature and pressure. BGAMon can be used to see the saturation point (maximum amount of water vapor) for your operating temperature and pressure. It may be necessary to operate at an elevated temperature if the water vapor is approaching condensation.

As with any REL, this technique works best near the conditions the REL was performed at. This means operating at a similar temperature, pressure and (most importantly) amount of water vapor in the wet air. Errors will increase the as the operating conditions move further away from the REL conditions. Refer to *REL to a Reference Gas* (page 104) for more details about this procedure.

Procedure

It is usually a good idea to know the approximate amount of water in the air before performing a REL. This serves two purposes. First it determines if the cell temperature should be increased using the heaters to avoid condensation. Second it provides a check to see if the amount of water vapor has changed since the unit was last REL'd.

Select dry air and water in the gas selection menu. Flow 100% wet air through the cell. If a condensation warning occurs, increase the cell temperature using the block heaters. Record the amount of water vapor in the wet air to compare with future measurements. A new REL should be performed whenever the amount of water vapor changes. It may be helpful to track the atmospheric temperature and relative humidity.

Next select dry air and the second gas to be measured in the gas selection menu. Be sure that wet air is still flowing through the cell. Go to the REL menu, select “Use REL” and press either [REL to 0%] or [REL to 100%], depending on your measurement. (Remember that the BGA244 graph reports the fraction of gas 1 in the mixture.) Return to the Home page. The reading should be very nearly the exact value selected on the REL page, either 0 or 100 %.

Water Vapor in Other Gases

This technique is generally applicable to any gas that contains water vapor.

Pressure

Pressure Effects in Gases

Several thermodynamic properties of gases have pressure dependent terms that cause their behavior to diverge from the ideal gas law. These effects are significant for some gases. Sudden changes in pressure may also cause transients in the measured readings. See *Transients* (page 100) in this chapter for more details.

The largest departure from the ideal gas law is caused by intermolecular effects (effects between gas molecules). This causes a change in the speed of sound as a function of pressure. See *Chapter 8: Theory of Operation* for more information. The graph below shows the shift in the speed of sound for pure SF6, a gas with a fairly large frequency shift vs pressure.

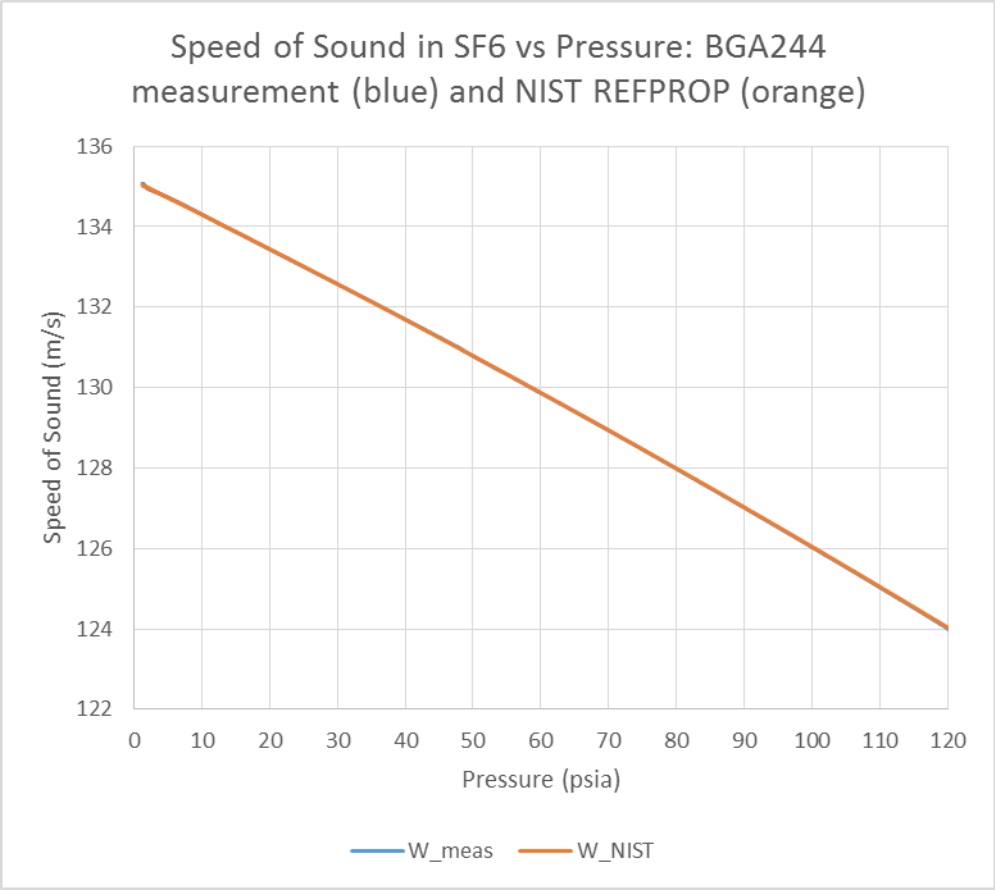


FIGURE 18: SPEED OF SOUND IN SF6 VS PRESSURE

These frequency shifts directly affect the Gas Purity and Physical Measurements modes. Their effect on the binary gas ratio is more complicated, since this also depends on the relative molecular weights of the two gases. The graph below shows two traces for a mixture with xx% SF_6 in N_2. One trace shows the change in the reported concentration assuming a fixed pressure of 14.7 psi (101 kPa). The second shows the change in reported concentration using the actual measured pressure.

Is Pressure Information Necessary?

There are cases where the BGA244 can make satisfactory measurements without precise pressure information.

- Best accuracy is not required.
- Some gases have small variations due to pressure.
- The REL function can be used to improve accuracy at a fixed pressure.

Unless one or more of these is true, it's necessary to know the gas pressure. The *BGAMon* software can indicate measurement sensitivity to pressure variations.

To meet the specified accuracy for all gases, the pressure must be known to within ± 1 psi (6.9 kPa). This information can be directly entered into the BGA244 or measured by a pressure transducer interfaced to one of the analog I/O ports as described in the *Pressure Transducers* (page 31).

Estimating pressure

Tip: If your system vents to the atmosphere, the operating pressure is probably around 1 atm (14.7 psia or 101 kPa).

Compensating using REL

The REL function can be used to compensate for a lack of pressure information in some cases. This technique works best when deviations from a reference gas or mixture are more important than the absolute accuracy. It is most accurate for small deviations from the reference point; larger deviations are less well compensated. This REL will only be valid for the gas or mixture it was performed on. A new REL should be performed whenever anything that can affect the gas pressure is changed. This may include different flow rates, new gas cylinders, regulators or MFC's.

Minimum Operating Pressures

The minimum operating pressure that the BGA244 can make reliable measurements depends on the mass of the gas mixture. Below this minimum the BGA244 cannot reliably recover the acoustic signal. A "No Signal" message will be displayed in place of the measurement if this occurs. (See *Screen Messages*, page 49 for details). The following table lists typical minimum pressures for pure gases. All values are listed in absolute pressure units (relative to vacuum). Use Averaging at low pressures to improve the detection limit and stability of measurements. The default value of 10

averages is a good place to start, but values of 20 or more may be necessary for extremely low pressures.

TABLE 18: MINIMUM DETECTION PRESSURES FOR PURE GASES

Gas	Minimum Pressure
H_2	10 psia (69 kPa)
He	10 psia (69 kPa)
CH_4	4 psia (27 kPa)
N_2	1 psia (7 kPa)
Ar	1 psia (7 kPa)
CO_2	13 psia (90 kPa)
SF_6	1 psia (7 kPa)

Pure CO2 (carbon dioxide) has an especially high minimum detection pressure due to relaxation effects. Adding even a small amount of a second gas reduces the detection pressure dramatically. Refer to *Relaxation Effects* (page 92) for more details.

Since the average mass of the gas is what sets the minimum detection pressure, mixtures of He or H_2 and any other gas will be able to be measured at lower pressures than pure Helium or Hydrogen.

Ambient Pressure Variation

Ambient pressure varies only slightly due to weather. The default ambient pressure is 14.7 psia (101 kPa) which corresponds to the average atmospheric pressure at sea level. A typical low ambient pressure at sea level is about 14.5 psia (100 kPa); a typical high pressure is about 14.9 psia (103 kPa).

Elevation has a much larger effect on ambient pressure. The typical atmospheric pressure in Denver, Colorado at 5280’ (1610 m) is 12.2 psia (84 kPa). Setting the ambient pressure based on the elevation and ignoring any weather effects should only introduce a small error for devices using gauge pressure units. However for best accuracy the ambient pressure should be measured and updated whenever it changes by more than 0.5 psi (3.4 kPa).

Operating Conditions

Warm Up Time

The BGA244 can make measurements immediately after power-on. The accuracy may improve slightly after warmup due to thermal gradients stabilizing. Depending on the operating conditions, this can take up to 5 minutes for the internal temperature to completely stabilize. There may be a small change in reading during this time, depending on the specific measurement.

The temperature settling when the heaters are on varies on a number of factors including the ambient and set temperatures, the maximum heater current, gas temperature and flow. Examples for several different temperatures and heater current are listed below. See *Heater* (page 75) for information on setting the heaters.

TABLE 19: HEATER SETTLING TIME

Initial Temp	Final Temp	Max Current	Regulating	Settled
25 °C	40 °C	0.5 A	22 min	32 min
25 °C	50 °C	1.0 A	24 min	29 min
25 °C	70 °C	2.5 A	19 min	27 min

Response Time

The response time of the BGA244 is primarily a function of the gas flow rate required to turn over the volume of the acoustic cell (~ 130 cc). The following table shows the step response time for a 100% step in gas species assuming a constant temperature, pressure and flow rate. At low flow rates, changes in temperature or pressure may affect the settling time as described in *Transients* (page 100).

TABLE 20: RESPONSE TIME

Flow (sccm)	Settling to 10%	Settling to 1%	Settling to 0.1%
100	180 s	360 s	540 s
200	90 s	180 s	270 s
500	36 s	72 s	108 s
1000	18 s	36 s	54 s
2000	9 s	18 s	27 s
5000	4 s	7 s	11 s

High Flow Rate

The BGA244 is specified for flow rates up to 5000 sccm (5 liters/min). Customers have successfully operated at rates of up to 20,000 sccm (20 liters/min). At very high flow rates there may be some noise in the readings that averaging may help stabilize. See *Using Averaging* (page 103) for details.

Variations in flow rate can cause transients in the measurement results as described in *Transients* (page 100).

Transients

Changes in flow, pressure or gas temperature may cause small transients in the measured readings even if the gas does not change. This is caused by a disruption in the thermal profile in the BGA244 cell. The transient settles as the new thermal profile is established. The magnitude of the transient is a function of the measurement being made, the gases and the magnitude of change. The change in the speed of sound is typically less than 0.1%. The change for ratio measurements is typically less than the accuracy estimation. For the best accuracy allow the readings to settle after large changes in flow, pressure or gas temperature.

A cell in equilibrium has a temperature profile that is a function of the gas mixture, flow rate, pressure, temperature of the gas and the temperature of the BGA244 gas cell. The thermistors measure the temperature at 2 specific points in that distribution. If any of the conditions change, a new temperature profile will gradually be established. The thermistor temperature will lag the overall gas temperature until the new equilibrium is reached. How long it takes to reach this new equilibrium is a function of the thermal conductivity and flow rate of the gas.

For low flow rates (<100 sccm) settling occurs primarily through the thermal conductivity of the gas in the cell. This typically takes less than 60 seconds and depends heavily on the gas species. The following table shows the transient settling time for a few different gases at zero flow.

TABLE 21: LOW FLOW TRANSIENT SETTLING TIME

Gas	Transient Settling Time
H_2	10 s
He	11 s
N_2	41 s
Ar	60 s
SF_6	83 s
Kr	113 s

At higher flow rates (> 100 sccm) settling becomes more of a property of the gas flow rate. The gas at the thermistors is replaced by outside gas, rather than relying on the thermal conductivity to reach equilibrium. The following table shows the transient settling time for Nitrogen (N2) at several flow rates.

TABLE 22: TRANSIENT SETTLING TIME FOR DIFFERENT FLOW RATES

Flow (sccm)	Transient Settling Time
100	41 s
200	41 s
500	22 s
1000	21 s
2000	20 s
5000	20 s

Interference

Vibration

Mechanical vibrations can be picked up by the BGA244. This causes an interfering signal that can make measurements noisy or even impossible to make. The best solution is to make sure that the BGA244 is mounted in a vibration and impact free location. Follow the mounting guidelines in *Chapter 2: Installation Guide*.

Averaging may help stabilize the readings. It may require a large number of averages to suppress a large interfering signal. You may need to experiment to find the proper balance between stable answers and response time. See *Using Averaging* (page 103) for more details.

Electrical and Magnetic Interference

Even though the BGA244 is shielded for EMI, motors or transformers can generate large enough fields to overwhelm the acoustic transducer signals. It may be necessary to add shielding if the BGA244 and the interfering source cannot be separated far enough apart. For low frequencies (<1 kHz) use cold rolled steel. At higher frequencies (> 1 kHz) conductive materials (copper or aluminum) can be used. Avoid passing currents through the BGA244 from the gas lines. This can generate interfering signals. Make sure that all pipes are properly grounded.

Averaging may help stabilize the readings. It may require a large number of averages to suppress a large interfering signal. You may need to experiment to find the proper balance between stable answers and response time. See *Using Averaging* (page 103) for more details.

Measurements

In most cases the BGA244 can make accurate measurements right out of the box without any adjustments or fine tuning. However certain measurements may benefit from the following techniques.

Temperature Variations

The BGA244 measures the gas temperature as part of its measurements. However large ambient temperature changes or extremely precise measurements may benefit from operating the Block Heater to stabilize the cell temperature.

The Block Heater is typically operated at least 3-5 °C above the highest expected ambient temperature. The Maximum Heater Current should be large enough to raise the cell temperature at least 5-10 °C above the set temperature. This is normally between 0.5 and 2 A.

Evacuating Cell

At very low flow rates it can take a long time for changes in gas concentrations to completely settle to their final value (see *Response Time*, page 99).

Rather than wait until the total volume of the cell turns over several times, it may be much faster to first evacuate the cell and then refill it. This speed is at the expense of additional complexity in the gas manifold. A vacuum pump and inlet and outlet valves are required. But in some cases, most of this may already be part of the system. For extremely precise measurements it may be necessary to allow the cell to reach thermal equilibrium prior to getting completely settled measurements.

Using Averaging

Averaging successive measurements can improve accuracy and repeatability of the measurements by reducing interfering signals and noise. However this occurs at the expense of having a slightly slower response to changes in the measurement. The BGA244 takes a measurement every 228 ms which is quite a bit faster than most processes change. A moderate number of averages doesn't affect the response time and can minimize variations in a measurement.

The averaging method used in the BGA244 cancels out any signals that are not synchronous to its measurement signal. This suppresses interfering signals and noise as a function of the number of averages.

Averaging can dramatically reduce the noise on a signal. The graph shown is for Argon in Air. Because the speeds of sound of the two gases are similar, the signal is fairly noisy. Using 10 averages decreases the peak variation by about 4 times.

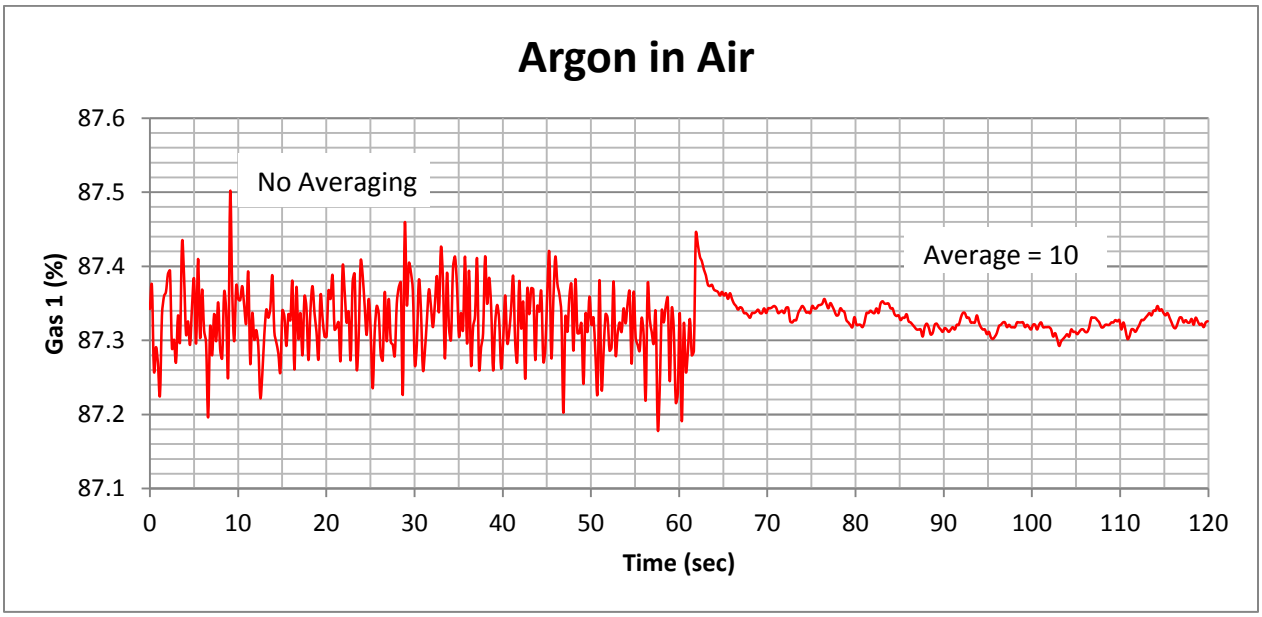


FIGURE 19: GAS CONCENTRATION WITH AND WITHOUT AVERAGING FOR ARGON AND AIR

Larger numbers of averages may be required to suppress interfering signals or recover low pressure signals in the presents of a lot of noise. This will slow the response time. You may need to experiment to find the best balance between stable answers and response time. See *Averaging* (page 72) for details.

REL to a Reference Gas

Using REL to a reference gas can help improve measurements by removing uncertainties in the temperature, pressure and other parameters. The procedure involves flowing a reference gas through the cell and then nulling the measured value to the expected value. This technique works well near the conditions at which it was performed. Errors increase as the operating conditions move the further away from the REL conditions.

The BGA244 is relatively insensitive to variations in temperature, pressure or flow. However large changes in the operating conditions will produce measurable changes in the measurements. The REL should be repeated whenever a significant change in the operating conditions occurs. This would include changes in temperature, pressure and flow or changing the gas used as the reference (new gas bottle).

A Reference Gas is usually:

- One of the two gases in a binary mixture
- An extremely well measured blend of the gases
- The pure Gas for the Gas Purity Mode

The usual magnitude of the correction in a REL for a Reference Gas is a few percent or less. A larger than expected REL value may indicate that the gas you are using for a reference isn't as pure as expected.

It is best to perform a REL as close to the operating condition as possible. This means operating at the same pressure, flow rate and temperature. Note that the REL function refers to the value of Gas 1 in the Binary Gas Analyzer Mode.

There are two techniques to purge the acoustic cell of all residual non-Reference gas.

- Flow the Reference Gas until the measurements have completely settled. This may take may take many minutes to remove any residual gas, especially at low flow rates.
- Evacuate the acoustic cell to vacuum prior to flowing the Reference Gas. This takes only a few seconds, but requires additional valves and pumps.

Caution: The accuracy of readings after setting a REL depends on how well the REL was performed. Be sure that the measurement has completely settled before performing the REL.

Procedure

Use one of the techniques to purge the acoustic cell to ensure that the pure Reference Gas is all that is in the acoustic cell.

Set the number of averages (N) between 20 and 60. Allow the reading to completely stabilize. Remember that it takes about N * 1.14 seconds for measurements to settle. Refer to *Averaging* (page 72) for details.

Select (Use REL). Press [REL to 100%], [REL to 0%] or enter the <REL Value> directly as described in *REL* (page 59).

Return to the Home page. The reading should be very nearly the exact value that was selected on the REL page.

Converting Molar Fraction vs Mass Fraction

The ratio of the two gases can be reported as either a mole fraction or a mass fraction. These differ only by the atomic weights of the gases. Mole fraction is the ratio of the number of molecules of one gas relative to the total number of molecules in a volume. Mass fraction is the ratio of the mass of one gas relative to the total mass of the gas in the volume.

Mole fraction is commonly used in gas blending, while Mass fraction is used in monitoring combustion products. The BGA244 supports both methods.

The formula for converting from mole fraction to mass fraction is:

$$w1 = \frac{(x1 * M1)}{(x1 * M1) + (x2 * M2)}$$

and for converting mass fraction to mole fraction:

$$x1 = \frac{({}^{w1}/_{M1})}{({}^{w1}/_{M1}) + ({}^{w2}/_{M2})}$$

where *w*1 = mass fraction of gas 1, *x*1 = mole fraction of gas 1, *M*1 = mass of gas 1 and *w2* = mass fraction of gas 2, *x*2 = mole fraction of gas 2, *M*2 = mass of gas 2.

Example: Determine the mass fraction of Nitrogen in air
For the simple 2 gas case (ignoring other gases), air made up of 78% Nitrogen molecules (N_2) and 22% Oxygen molecules (O_2). In this case, the mole fraction of Nitrogen in air is 78% or 0.78.

$$Mass\ Fraction\ N2 = \frac{0.78 * 28.01348}{(0.78 * 28.01348) + (0.22 * 31.9988)} = 0.756$$

Example: Determine the mole fraction of Hydrogen (H_2) for a mixture of 1 kg Hydrogen and 100 kg Carbon Dioxide (CO2).

$$Mole\ fraction\ of\ H2 = \frac{\left(\frac{1}{101}/2.01588\right)}{\left(\frac{1}{101}/2.01588\right) + \left(\frac{100}{101}/44.0098\right)} = 0.179$$

Accuracy & Stability

Binary Gas Measurement Accuracy

In the Binary Gas Analysis mode, the gas concentration is determined by measuring the speed of sound of the gas in the cell and its temperature. The amount of each gas is calculated based on these measurements and their physical properties. As described in *Chapter 8: Theory of Operation,* the speed of sound for an ideal gas is:

$$W = \sqrt{\frac{\gamma RT}{M}}$$

So at a given temperature T, the speed of sound is proportional to

$$\sqrt{(\frac{\gamma}{M})}$$

Since γ (the ratio of specific heats) only varies between 1 and 1.67, changes in the speed of sound are largely due to the change of mass, which can vary from 2 to around 200. Because of this, the BGA244 has the best resolution and accuracy when the difference in molar mass of the two gases is largest. After the molar mass, the next most influential parameter is γ (gamma). After these there are several non-ideal gas properties that cause additional shifts. The BGA244 accounts for all of these factors.

The best measurement sensitivity occurs when measuring a small amount of a heavy gas in a lighter gas. Absolute accuracies at the 10 ppm level are possible for a small amount of an extremely heavy gas with a carrier of Helium or Hydrogen.

> **Example:** Measuring the ratio of 1% SF_6 (mass 146) in Helium (mass 4) gives an estimated accuracy of ~0.0015% (15 ppm).

Using the REL mode cancels out the uncertainties in temperature and pressure. With this relative accuracies at the ppm level are achievable.

Poor Sensitivity

The measurement sensitivity suffers for mixtures where both gases have similar speeds of sound. This leads to somewhat poorer estimated accuracy.

> **Example:** Nitrogen (mass 28) and oxygen (mass 32) have similar speeds of sound (around 349 and 326 m/s). At an 80%/20% ratio, the estimated accuracy is 0.24%.

Problem Mixtures

Other gas mixtures can be even more problematic. In some gas combinations, over a portion of their range there can be two different gas ratios which have the same speed of sound. (In these cases, the speed of sound is not a monotonic function of composition. Argon/oxygen is a notorious example.). Both of these ratios are equally valid as far as the BGA244 can determine. The BGA244 detects if this occurs and reports both solutions (Two Solutions) as described in *Screen Messages* (page 50).

These mixtures can be measured in some circumstances. For a portion of their range there is only the single molar ratio value. Or if the approximate ratio is known the larger or smaller solution can be selected.

These mixtures normally are for gases with slightly different molar masses and different molecular types (monatomic, diatomic or polyatomic). The effect can be modulated by temperature and pressure. You can determine if this problem exists for your gas combination, pressure and temperature using BGAMon. In some cases this effect can be minimized by operating at a different pressure or temperature.

This problem exists for any binary gas analyzer that relies on the thermodynamic properties of gases, including those measuring time of flight or thermal conductivity. It may be more visible on the BGA244, because it supports so many different gas pairs and concentrations. This doesn't necessarily occur for the same gas pairs, but does occur for some pairs for all techniques. Most other analyzers support at most, a hand full of gas combinations and will not support combinations or ranges where this can occur.

> **Example:** A common mixture that exhibits this behavior is Argon (mass 36, γ = 1.67) in Oxygen (mass 32, γ = 1.45). At NTP there is a single solution reported for 0 – 43.5%, but two solutions above that.

Gas Purity Measurement Accuracy

In the Gas Purity Analysis mode, the measured speed of sound of the gas in the cell is compared with expected speed of sound. This measurement is sensitive to small amounts of a contaminating gas. However the magnitude of the reported value depends on the species of the contaminating gas. See Table 9 (page 45) for an example of this. Gas Purity measurements are most sensitive when the contaminating gas(es) have a much higher or lower speed of sound. Gases with similar speeds of sound are problematic. Higher speeds of sound are normally associated with lighter gases, while slower speeds of sound are associated with heavier gases.

Example:
1% of He (a lighter gas) in N_2 give a purity measurement of ???%.
1% of SF_6 (a heavier gas) in N_2 gives a purity measurement of ??%.
1% of O_2 (similar mass) in N_2 gives a purity measurement of ??%.

This problem becomes more difficult when dealing with multiple contaminating gases. If the reading is positive the combined contaminants are lighter gases. If negative, the contaminants are usually heavier. However it is possible for the contaminant to be a mixture of both heavier and lighter gases. In this case measurements can be unpredictable.

Long Term Stability

Measurements made by the BGA244 are extremely stable, assuming no dramatic changes in the operating conditions. Long term aging effects are in the ppm level.

Changes in ambient temperature of a few degrees will produce ?? ppm level changes in the speed of sound. This corresponds to the same relative change in Gas Purity measurements. The change for binary gas measurements is more complicated and depends largely on the gas species. The graph below shows drift in the speed of sound and gas concentration measurements versus time for mixture x.

High Purity Use

Certain applications are extremely sensitive to any contamination. These may involve low flow rates, sensitivity to contamination, operating below atmospheric pressure or a combination of these. The following section provides some guidelines to help minimize contamination in sensitive systems.

Fittings and tubing

Metal tubing and all metal seals should be used. Avoid elastomeric seals as they are porous and prone to outgassing. VCR fittings (options A, B & H) are recommended for applications operating below atmospheric pressure. Use welded VCR fittings (option H) for the most stringent contamination requirements.

Leak Testing

All BGA244s are leak tested at the factory. Leak tests are commonly performed on systems after any significant changes are made to the gas manifold or fittings. Depending on the application either outbound or inbound leak testing may be appropriate.

Dead Volumes

There are several small volumes in the BGA244 that are poorly vented to the cell. These total about 1 cc and vent to the cell by diffusion through fairly low conductance paths.

For normal operation these volumes contain the same gas as the rest of the cell and have no effect on measurements. However if the gas species has changed significantly, the gas in these volumes will gradually diffuse into the cell over a few minutes. The diffusion occurs faster for lighter gases than for heavy gases. For low flow rates this may introduce a small error for the first few minutes after the gas species has changed.

If this presents a problem, the cell can be briefly evacuated under vacuum to vent these volumes. Otherwise flow gas for a few minutes to allow these volumes to diffuse into the cell.

Outgassing

Outgassing is only a concern when a cell has been exposed to moist air, solvents, or if the gas species in the cell have changed. Normally it can only be detectable at very low flow rates and will diminish over time. To accelerate outgassing, follow the Degas procedure later in this section.

The primary source of outgassing in the BGA244 is the Kapton acoustic transducers. While Kapton has excellent resistance to nearly all chemicals, it is hydrophilic and porous to some gases. Substances that are readily absorbed by Kapton include water, alcohols and many solvents (generally polar molecules).

There is about 2.9 in^2 (18.5 cm^2) of 1 mil (0.025 mm) thick Kapton in the two acoustic transducers. If fully saturated, they can absorb around 2.7 g of water. At NTP this becomes about 3.3 cc of water vapor. Similar amounts of other polar molecules will also be absorbed.

Kapton is also somewhat porous to many gases. Gases present in the cell will diffuse into the transducers. If the gas is changed or the cell is put under a vacuum, this gas will gradually diffuse out. This will have no effect if the gas species hasn't changed, but it can be detected if the cell is filled with a different gas or under vacuum.

Does outgassing matter? In most cases it will be completely undetectable. At room temperature, the outgassing rate of Argon, Nitrogen or water vapor starts at about $5x10^{-5}$ sccm and decreases over time. For a 10 sccm flow this corresponds to a contamination of a few ppm.

The outgassing rate can be decrease to about $5x10^{-7}$ sccm by using the following Degas procedure. This corresponds to a contamination of 0.05 ppm for the same 10 sccm flow.

Minimize exposure to the atmosphere or other contaminants to reduce the amount absorbed. Fill the cell with a dry gas and cap it off if not in use. Follow the Degas procedure if exposure has occurred or different gasses are being used.

Degas

The Degas and Block Heaters can be used to dramatically reduce the outgassing rate of the Kapton transducers. This procedure is optimally done under vacuum where the outgas rate can be monitored. If necessary it can also be done while flowing a dry gas through the cell for an extended period of time.

Degas requires Option 1 and an external +24 V power supply rated for at least 1A. If degas is being done under vacuum, a residual gas analyzer, ion gauge or other suitable vacuum gauge can be used to track the outgassing rate until it reaches an acceptable level. The SRS RGA100/200/300 and IGC100 are well suited for this. Refer to *Heaters* (page 75) for details on operating the heaters.

Under Vacuum

Set the block heaters to 70 °C and turn on Degas. The initial outgassing rate of the Kapton transducers will be around $1x10^{-6}$ sccs for water vapor, Argon or Nitrogen. After the heaters are first turned on, the rate will initially increase. Typically the rate should be around $5x10^{-7}$ sccs after a few minutes and then decrease exponentially over time.

Run degas until the rate has dropped to around $1x10^{-8}$ sccs or whatever level is acceptable if the outgas rate is being monitored. Otherwise run for at least 2 hours.

When complete, turn off Degas and set the Block Heater to its operating value. Remember that the BGA244 cannot make gas measurements under vacuum. Fill the cell with a dry gas and cap it off if not in use.

While Flowing Gas

This procedure can also be performed while flowing a dry gas through the BGA244. It may take longer to reach the same outgas rate since the Kapton transducers are cooled by the flowing gas. Ideally the dry gas should be one of the gases being used in operation so a different gas species isn't absorbed into the membrane.

Set the block heaters to 70 °C and turn on Degas. Flow at least 10sccm of the dry gas through the BGA244. Run Degas for at least 2 hours. This should reduce the outgas rate to $< 1 \times 10^{-8}$ sccs.

When Degassing is completed, turn off Degas and set the Block Heater to its operating value. Remember that the BGA244 cannot make gas measurements when Degas is on. Fill the cell with a dry gas and cap it off if not in use.

User Gases

The BGA244 Factory Gas Table contains nearly 500 different gases. However there are many more gases that can be measured, including mixtures or blended gases. Blended gases are made up of two or more single species gases. The BGA244 supports a User Gas Table that allows a nearly unlimited number of new gases to be added by the end user.

Gases in the BGA244s Factory Gas Table have detailed information about how a gas behaves over a wide temperature and pressure range, as well as how it interacts with any other gas. However gases don't need to be specified this completely to be able to make accurate measurements, especially at fairly constant temperatures and pressures.

Factory Gas Table

The Factory Gas Table contains a comprehensive list of data for each gas, including names, formula, molecular weight and various thermodynamic properties. This information allows accurate measurements to be made on a wide variety of gases over the entire operating range of the BGA244.

See *Appendix A (Gas Table)* and *Chapter 8: Theory of Operation* for a detailed explanation of all of the terms contained in the Factory Gas Table and their effects on measurements.

User Gas Table

The User Gas Table is used to store data on gases that aren't available in the Factory Gas Table. This information is stored using the BGAMon Software.

Typically only a subset of the physical properties contained in the Factory Gas Table are entered for new gases in the User Gas Table. The following parameters can be entered for User gases: Name, molecular weight, specific heat, expansion of specific heat over temperature.

Selecting a User Gas

User gases show up in gas selection searches as "User/Gas Name". See *Selecting Gases* in the *Operations Guide* for more information.

Adding a User Gas with BGAMon

Determining Gas Coefficients

All User gases must have a name, molecular weight and some thermodynamic data. The name is used when selecting the gas and to display on the Home page. The molecular weight is the atomic weight of the gas. Differing amounts of thermodynamic data can be entered, ranging from a single parameter to complete specifications.

The following section describes the simplest model for a gas: the molecular weight and a single thermodynamic property: C_P (specific heat at constant pressure). This model assumes that the gas follows the ideal gas law. This is a reasonable approximation of the behavior of many gases, especially at constant temperature and pressure.

See *Appendix A* (Gas Table) for details on obtaining a more complete set of parameters for a gas.

Finally remember that repeatability is often more important than accuracy. As long as you operate at a similar temperature and pressure, the measured values won't change even if you don't have a precise value for C_P. Using the REL function can compensate for less than perfect parameters.

Mass

Finding the mass of the gas is fairly simple. For a single species gas, it's just the molecular weight in AMUs (atomic mass units).

To find the molecular weight of a blended gas, take the molecular (mole) fraction of each gas times its weight. MF1 and MF2 are the mole fractions of each gas.

$$mass = (mass1 \times MF1) + (mass2 \times MF2)$$

C_P

The minimum thermodynamic property required for a gas is C_P, the specific heat at constant pressure. *Cp* is related to the heat capacity ratio γ (gamma) of the gas by the following equation.

$$Cp = \frac{\gamma R}{\gamma - 1}$$

Both *γ* (gamma) and C_P values for many gases can be found in literature or on line.

A simplified value for C_P can be entered into the User Gas Table by variable a_0, where

$$a_0 = C_P / R = \gamma/(\gamma-1)$$

Both C_P and *R* can be expressed in different units. Make sure that you use the same units for both C_P and *R* when calculating a_0.

The following rules are generally true for single species gases at room temperature and near atmospheric pressure:

- Monoatomic gases $a_0 \approx 2.5$
- Diatomic gases $a_0 \approx 3.5$ - 4
- Polyatomic gases $a_0 \approx 3.5 – 50$

Try to obtain values for *γ* or C_P at or near the temperature and pressure the BGA244 will be operating for best accuracy.

In contrast to the mass, finding a_0 (or *γ or* C_P*)* for single species gases can be more difficult than that of a blended gas. Since the factory gas table already contains most of the monoatomic and diatomic gases, new non-blended gases being added are almost always polyatomic. For most of these gases, *a0* varies from 3.5 – 11.

> **Hint:** If you can't find a value for a_0 for the gas you are adding, use a value from a similar gas.

Calculating *a0* is relative simple for blended gases, assuming *a0* is available for each species of the blend. a_0 mixes as the mole fraction of the two gases. (Note that *γ* does not). Take the mole fraction of each gas times its value for a_0. MF1 and MF2 are the mole fractions of each gas.

$$a0\ (blend) = \ (a0gas1 \times MF1) + \ (a0gas2 \ \times MF2)$$

Adding Gases

Example: Adding a Single Species Gas (Argon)

To add a gas, at a minimum you need the three previously mentioned items: a name, molecular weight and a_0. For this example we will add a simple model for Argon to the User Gas Table.

- Name = Argon
- Molecular Weight = 39.95
- a_0 = 2.5 (Argon is monatomic)

Example: Adding a Blended Gas (Air)

Blended gases are made up from two or more single species gases. The molecular weight and a_0 must be calculated based on the ratio of the gases in the blend.

The most familiar blended gas is air. As a commercial product, air is usually considered to be 79% Nitrogen and 21% Oxygen.

To find the molecular weight of the gas, take the mole fraction of each gas times its weight.

Gas	Mol Fraction	Mol Weight	Fraction Weight
N2	0.79	28.02	22.14
O2	0.21	32.00	6.72
Sum			28.86

Note that the molecular weight is slightly different than the value from the Factory Gas Table. This is because Air in the Factory Gas Table is atmospheric air (78.09% N2, 20.95% O2, 0.93% Ar). The extra mass of Argon (39.95) increases the mass slightly. However since it is such a small fraction of the total it has no real effect on the thermodynamic data.

- Name = Air
- Molecular Weight = 28.86
- a_0 = 3.5 (both gases are diatomic)

Example: Adding a Blended Gas (Heliox)

Another common blended gas is Heliox 80:20 ($He:O_2$). The calculations are a little more complicated than air since Helium is monatomic and Oxygen is diatomic.

To find the molecular weight of the gas, take the mole fraction of each gas times its weight.

Gas	Mol Fraction	Mol Weight	Fraction Weight
He	0.80	4.03	3.22
O2	0.20	32.00	6.40
Sum			9.62

a_0 mixes as the mole fraction of the two gases.

To find a_0 for the gas, take the mole fraction of each gas times its value for a_0.

Gas	Mol Fraction	a_0	Fraction a_0
He	0.80	2.50	2.0
O2	0.20	3.50	0.7
Sum			2.7

- Name = Heliox 80-20
- Molecular Weight = 9.62
- a_0 = 2.7 (calculated above)

Operating with User Gases

Typically there will be larger pressure and temperature dependent errors associated with User entered gases, since they are not specified as thoroughly as factory gases. Try to operate at a fairly constant temperature and pressure to avoid these errors.

Changes in gas parameters with temperature and pressure may create significant errors in some cases. But there are plenty of situations where they will have an insignificant effect.

- If the User gas is used as a dopant to a much lighter factory gas, the differences in mass may overwhelm any small errors in the gas model.
- The thermodynamic properties of the user gas may not vary much over the operating pressure and temperature range.
- Many processes depend more on changes in values rather than the actual value. REL can be used to establish a baseline and track variations from that value.

If possible, find values for a_0 (γ or *Cp)* at or near the operating temperature and pressure for best accuracy. Operate at a stable temperature. The block heater is an easy way to achieve this.

Using REL with User Gases

In some cases the BGA244 will operate at high concentrations of the User gas. In this case you can REL to the User gas as a Reference. Follow the procedure *REL to a Reference Gas* described earlier in this chapter.

Chapter 5: BGAMon

BGAMon

Entering the User Gas Table

Updating Firmware

Chapter 6: Remote Programming

Introduction

The BGA244 can be remotely programmed over the USB interface, the RS-232 serial interface, or the optional RS-422 interface. Any host computer interfaced to the instrument can easily control and monitor its operation.

Note that the RS-422 interface is only available if the Industrial Control Option (Option 1) is installed and a 24 V supply is connected to the BGA244.

Interface Configuration

The interface configuration parameters can be controlled from the Computer I/O pages located at (Home/Setup/Control Panel/Computer IO). See *Computer I/O* (page 76) for details.

The only two configuration parameters are the baud rates for the RS-232 and RS-422 interfaces. The default baud rate for both interfaces is 9600 baud. All interfaces are enabled by default, but the RS-232 and RS-422 interfaces may be disabled individually if desired. Any modification made to an interface takes effect immediately.

Responses to commands are returned to the interface that sent the command. For example if you query “*ESE?” over RS-232, the reply will only be sent back over the RS-232 interface.

Front-Panel Indicators

Two front panel LED indicators located to the right of the RS-232 connector help assist with programming: COMM and ERR. The COMM LED is an activity indicator that flashes every time a character is received or transmitted over one of the remote interfaces. The ERR LED will flash when a remote command fails to execute due to illegal syntax or invalid parameters.

Transmit and Receive Buffers

Each interface has its own set of transmit and receive buffers that show the most recent commands and responses over that interface. These can be helpful for remote interface debugging. The buffers are located on the specific computer I/O pages (Home/Setup/Control Panel/Computer IO). See *Computer I/O* (page 76) for details.

Break Signal

The RS-232 and RS-422 interface supports a “break condition”. This is a non-command based, low level abort signal used to reset the interface if communications are locked. When a “break” is received, the input and output queues and buffers are all flushed. Any currently in-process “set” commands are completed, but no responses are returned. Status bits are not modified when a break occurs. The break signal is a framing error of all zeros.

USB

A USB Type B communication port is included on the front panel of the instrument. The BGA244 complies with the High Speed USB 2.0 standard. Refer to *Computer Interfaces* (page 23) for details on cabling requirements when connecting the BGA244 to a host computer.

The appropriate software driver must be installed on the host computer to properly communicate with BGA244 over the USB interface. There are two separate drivers available for the BGA244: a Virtual Com Port (VCP) and a Direct Driver (USB driver + DLL). The VCP allows communication in the same fashion as any other COM port. The Direct Driver allows function calls to be embedded directly into a controlling program. Refer to *Using the USB Drivers* (page 172) for more information.

USB Configuration

There is no status information is available for the USB interface. The transmit/receive buffers can be viewed at (Home/Setup/Control Panel/Computer IO/USB/Buffer).

RS-232

An RS-232 communication port is included on the front panel of the instrument. This is a standard 9 pin DB, female connector configured as a DCE (transmit on pin 2, receive on pin 3). See *Computer Interfaces* (page 23) details on cabling requirements when connecting the BGA244 to a host computer.

RS-232 Configuration

The RS-232 interface can be enabled or disabled. Status information and the transmit/receive buffers can be viewed at (Home/Setup/Control Panel/Computer IO/RS-232).

In order to communicate properly over RS-232, both the BGA244 and the host computer must be set to the same configuration. The following baud rates are supported: 2400, 4800, 9600 (default), 19.2k, 38.4k, 57.6k and 115.2k. The remaining communication parameters are set as follows: no parity, 8 data bits, 1 stop bit and CTS/RTS hardware flow control.

RS-422

An RS-422 communication port is included on the front panel of the instrument as part of the Industrial Control Option (Option 1). It is configured as a 4 wire point-to-point, non-multidrop that is connected via a terminal strip. It supports single transmitter and receiver pair only (not multi-drop). See *Computer Interfaces* (page 23) details on cabling requirements when connecting the BGA244 to a host computer.

Note that the RS-422 interface requires that a +24V power supply is connected to the BGA244.

RS-422 Configuration

The RS-422 interface can be enabled/disabled. Status information and the transmit/receive buffers can be viewed at (Home/Setup/Control Panel/Computer IO/RS-422).

In order to communicate properly over RS-422, both the BGA244 and the host computer must be set to the same configuration. The following baud rates are supported: 2400, 4800, 9600 (default), 19.2k, 38.4k, 57.6k and 115.2k. The remaining communication parameters are set as follows: no parity, 8 data bits, 1 stop bit and no hardware flow control.

Command Syntax

Although the BGA244 doesn't communicate over GPIB, its commands follow IEEE-488.2 Standard. All commands use ASCII characters, are 4-characters long, and are case-insensitive. Standard IEEE-488.2 defined commands begin with the '*' character followed by 3 letters. Instrument specific commands are composed of 4 letters.

The four letter mnemonic (shown in capital letters) in each command sequence specifies the command. The rest of the sequence consists of parameters.

Commands may take either *set* or *query* form, depending on whether the '?' character follows the mnemonic. *Set only* commands are listed without the '?', *query only* commands show the '?' after the mnemonic, and *query optional* commands are marked with a '(?)'.

Parameters shown in { } and [ ] are not always required. Parameters in { } are required to set a value and are omitted for queries. Parameters in [ ] are optional in both set and query commands. Parameters listed without any surrounding characters are always required.

Do NOT send () or {} or [ ] as part of the command.

The command buffer is limited to 64 kbytes, with 25 byte buffers allocated to each of up to 3 parameters per command. If the command buffer overflows, both the input and output buffers will be flushed and reset. If a parameter buffer overflows, a command error will be generated and the offending command discarded.

Commands are terminated by a semicolon, a <CR> (ASCII 13), or a <LF> (ASCII 10). Execution of the command does not begin until a command terminator is received.

Errors

Aside from communication errors, commands may fail due to either syntax or execution errors. Syntax errors can be detected by looking at bit 5 (CME) of the event status register (*ESR?). Execution errors can be detected by looking at bit 4 (EXE) of the event status register. In both cases, when an error occurs the red ERROR LED will flash and an error code indicating the specific cause of the error is placed in the error buffer. The error buffer may be queried with the LERR? command. Descriptions of all error codes can be found in the *Error Codes* section of this chapter, starting on page 168.

Parameter Conventions

The command descriptions use parameters, such as i, d, and v. These parameters represent integers or floating point values expected by the command. The parameters follow the conventions summarized in Table 24.

TABLE 23: COMMAND PARAMETER CONVENTIONS

Parameter	Meaning
i, j, k	An integer value
d	A floating point value
p	A floating point value representing a pressure in global units
v	A floating point value representing a speed in global units
r	A floating point value representing a ratio in global units
t	A floating point value representing temperature in global units
s	An ASCII string
u	An identifier of units. Allowed units depend on the type as identified below:

Type	Allowed Units
Ratio	'%', 'ppm' or 'Fr'
Speed	'm/s', 'kph' or 'mph'
Temperature	'C', 'K', or 'F'
Pressure	'psi', 'atm', 'bar', 'Pa', 'mmHg' or 'torr'

Numeric Conventions

Floating point values may be decimal ('123.45') or scientific ('1.2345e2'). Integer values may be decimal ('12345') or hexadecimal ('0x3039').

Measurement Errors

If an error in a measurement command occurs, the unit will return an overload value (9.9E37) to inform the user that there was something wrong with the measurement. The controlling program should test for this value and check the appropriate Status bytes to determine what the problem is.

Missing Options or Power Supplies

Commands that require an installed option or power supply that is not present, will generate an execution error. See the *Chapter 3: Operations Guide* for details on which functions require installed options and the 24V power supply.

If a command cannot be successfully executed because of a missing Option 1, an Error 16 (No Option 1) is generated. Similarly if a command cannot be successfully executed because of a missing 24V power Supply, an Error 17 (No 24V Available) will be generated.

If a command requires 24V power supply, it is usually a good practice to query if the 24V is available using the EXPA command prior to sending the command. Similarly you can use the OPTN command to confirm an option is present before attempting to configure it. These can be done at the beginning of the controlling program during initialization.

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*CLS	Page 130	Clear Status
*ESE(?){i}	Page 130	Standard Event Status Enable
*ESR?	Page 130	Standard Event Status Register
*IDN?	Page 130	Identification String
*OPC(?)	Page 130	Operation Complete
*PSC(?){i}	Page 131	Power-on Status Clear
*RCL i	Page 131	Recall Instrument Settings
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Event Register Commands

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Analog Output Commands

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Detailed Command List

Common IEEE-488.2 Commands

***CAL?** — **Auto calibration**

This command currently does nothing and returns 0.

***CLS** — **Clear Status**

Clear Status immediately clears the ESR, BG0R, BG1R, FALR, ANAR, and EVNR registers as well as the LERR error buffer.

***ESE(?){i}** — **Standard Event Status Enable**

Set (query) the Standard Event Status Enable register {to i}. Bits set in this register cause ESB (in STB) to be set when the corresponding bit is set in the ESR register.

***ESR?** — **Standard Event Status Register**

Query the Standard Event Status Register. Upon executing a *ESR? query, the returned bits of the *ESR register are cleared. The bits in the ESR register have the following meaning:

Bit	Meaning
0	OPC – operation complete
1	Reserved
2	QYE – query error
3	DDE – device dependent error
4	EXE – execution error
5	CME – command error
6	Reserved
7	PON – power-on

Example

*ESR?	A return of ‘176’ would indicate that PON, CME, and EXE are set.

***IDN?** — **Identification String**

Query the instrument identification string.

Example

*IDN?	Returns a string similar to ‘Stanford Research Systems,BGA244,s/n004025,ver1.00.0B’

***OPC(?)** — **Operation Complete**

The set form sets the OPC flag in the ESR register when all prior commands have completed. The query form returns ‘1’ when all prior commands have completed, but does not affect the ESR register.

*PSC(?){i} Power-on Status Clear

Set (query) the Power-on Status Clear flag {to i}. The Power-on Status Clear flag is stored in nonvolatile memory in the unit, and thus maintains its value through power-cycle events.

If the value of the flag is 0, then the Service Request Enable and Standard Event Status Enable Registers (*SRE, *ESE) are stored in non-volatile memory, and retain their values through power-cycle events. If the value of the flag is 1, then these two registers are cleared upon power-cycle.

All other status registers are cleared at power on.

Example

*PSC 1	Set the Power-on Status Clear to 1.
*PSC?	Returns the current value of Power-on Status Clear.

*RCL i Recall Instrument Settings

Recall instrument settings from location i. The parameter i may range from 0 to 20. Location 0 is reserved for the recall of factory default instrument settings. Locations 1 to 20 are user configurable.

Example

*RCL 3	Recall instruments settings from location 3.

*RST Reset the Instrument

Reset the instrument to default settings. This is equivalent to *RCL 0. It is also equivalent to recalling Setup 0 (Default) at (Home/Setup/Store-Recall/Recall). See *Default Setup* (page 66) for a list of the Default settings.

Example

*RST	Resets the instrument to default settings

*SAV i Save Instrument Settings

Save instrument settings to location i. The parameter i may range from 1 to 20.

Example

*SAV 3	Save current settings to location 3.

*SRE(?){i} Service Request Enable

Set (query) the Service Request Enable register {to i}. Bits set in this register cause the BGA244 to generate a service request when the corresponding bit is set in the STB register.

*STB? Status Byte

Query the standard IEEE 488.2 serial poll status byte. The bits in the STB register have the following meaning:

Bit	Meaning
0	BG0B - BG0R summary bit
1	BG1B - BG1R summary bit
2	FALB - FALR summary bit
3	ANAB - ANAR summary bit
4	MAV – message available
5	ESB – ESR summary bit
6	MSS – master summary bit
7	EVNB – Event summary bit

Example

*STB? A return of '113' would indicate that BG0B, MAV, ESB, and MSS are set. BG0B indicates that an enabled bit in BG0R is set. MAV indicates that a message is available in the output queue. ESB indicates that an enabled bit in ESR is set. MSS reflects the fact that at least one of the summary enable bits is set and the instrument is requesting service.

*TRG Trigger

This command currently does nothing.

*TST? Self Test

Runs the instrument self test and returns 0 if successful. Otherwise it returns the encoded errors per the following table. Refer to *Self Test* (page 86) for more details.

Bit	Meaning
0	Reserved
1	Power Supply
2	Display
3	CODEC
4	Thermistors
5	Analog Output
6	USB
7	Transducer
8	Magnet Strength
9-15	Reserved

*WAI Wait for Command Execution

The instrument will not process further commands until all prior commands including this one have completed.

Example

*WAI Wait for all prior commands to execute before continuing.

Instrument Status Commands

Instrument Status Registers

ALRD — Disable All Alerts

Disable all Alerts on the GUI.

This command disables all Alerts from appearing on the GUI. It has no effect on any of the status registers or the actual Alert conditions.

Example

ALRD	This would stop any Alert messages from appearing on the BGA244 display.

ALRE — Enable All Alerts

Enable all Alerts on the GUI.

This command disables all Alerts from appearing on the GUI. It has no effect on any of the status registers. It is the equivalent to the [ENABLE ALL ALERTS] key on the Alerts page.

ANAE(?){i} — Analog Enable Register

Set (query) the ANAR enable register {to i}. Bits set in this register cause ANA (in STB) to be set when the corresponding bit is set in the ANAR register.

ANAI? Analog Status Register (Immediate)

Query the ANAI register. This register is not latched and reflects the value of the register the instant it was read. Refer to the *Instrument Status Register Model* (page 164) for a description of the different conditions reported. The bits in the ANAI register have the following meaning:

Bit	Meaning
0	Measure Out Current Alert
1	Measure Out Temperature Alert
2	Output 1 Current Alert
3	Output 1 Temperature Alert
4	Output 2 Current Alert
5	Output 2 Temperature Alert
6	Input 1 Over Current Alert
7	Input 1 Under Current Alert
8	Input 1 Over Voltage
9	Input 1 Under Voltage
10	Input 2 Over Current
11	Input 2 Under Current
12	Input 2 Over Voltage
13	Input 2 Under Voltage
14	Loop Power Alert
15	reserved

Example

ALAI? A return of '2048' indicates that Input 2 was under current.

ANAR? Analog Status Register (Latched)

Query the ANAR status register. This register is a latched version of the ANAI register. Upon executing an ANAR? query, the register is cleared. The meaning of the bits in the ANAR register is the same as the ANAI register.

Example

ANAI? A return of '1' would indicate that Measure Out had a current fault since the last time this register has been read or cleared.

BG0E(?){i} BGA Enable Status Register 0

Set (query) the BGA0 status enable register {to i}. Bits set in this register cause BG0B (in STB) to be set when the corresponding bit is set in the BG0R register.

BG0I? BGA Status Register 0 (Immediate)

Query the BGA0 status register. This register is not latched and reflects the value of the register the instant it was read. Refer to the *Instrument Status Register Model* (page 164) for a description of the different conditions reported. The bits in the BG0I register have the following meaning:

Bit	Meaning
0	2 Concentration Values (BGA Mode only)
1	Degas heater on
2	Measurement is stopped
3	Measurement is below allowable range
4	Measurement is above allowable range
5	No Signal
6	> 5 °C mismatch on temperature measurements
7	Cell Temperature < 0 °C
8	Cell Temperature > 70 °C
9	Bad Analysis Pressure Reading
10	Condensation Warning
11-14	reserved
15	Summary bit for Fault Register (FALR)

Example

BG0I? A return of '2' would indicate that the Membrane Heater is on.

BG0R? BGA Status Register 0 (Latched)

Query the BGA0 status register. This register is a latched version of the BG0I register. Upon executing a BG0R? query, the register is cleared. The meaning of the bits in the BG0R register is the same as the BG0I register.

Example

BG0R? A return of '192' would indicate that there had been a mismatch between the temperature sensors and that the temperature has exceeded < 0 °C since last read or cleared.

BG1E(?){i} BGA Status Enable Register 1

Set (query) the BGA1 status enable register {to i}. Bits set in this register cause BG1B (in STB) to be set when the corresponding bit is set in the BG1R register.

BG1I? BGA Status Register 1 (Immediate)

Query the BGA1 status register. This register is not latched and reflects the value of the register the instant it was read. Refer to the *Instrument Status Register Model* (page 164) for a description of the different conditions reported. The bits in the BG1I register have the following meaning:

Bit	Meaning
0	reserved
1	Heater is not Regulating
2	Measurement Meter Limits exceeded
3	Pressure Meter 1 Limits exceeded
4	Pressure Meter 2 Limits exceeded
5	Temperature Meter Limits exceeded
6	USB Voltage is over range
7	USB Voltage is under range
8	+24 V is over range
9	reserved
10	REL mode active
11	reserved
12	Password Lock
13	Average Settled (0 = settled, 1 = not settled)
14-15	reserved

Example

BG1I? A return of '1026' would indicate that REL mode was active and the Heaters were not regulating.

BG1R? BGA Status Register 1 (Latched)

Query the BGA1 status register. This register is a latched version of the BG1I register. Upon executing a BG1R? query, the register is cleared. The meaning of the bits in the BG1R register is the same as the BG1I register.

Example

BG1R? A return of '4' would indicate the measurement limit has been exceeded since last read or cleared.

FALE(?){i} Fault Enable Register

Set (query) the FALE enable register {to i}. Bits set in this register cause FALT (in STB) to be set when the corresponding bit is set in the FALR register.

FALI? Fault Status Register (Immediate)

Query the FALI register. This register is not latched and reflects the value of the register the instant it was read. Refer to the *Instrument Status Register Model* (page 164) for a description of the different conditions reported. The bits in the FALI register have the following meaning:

Bit	Meaning
0	Cell Under Temperature fault
1	Cell Over Temperature fault
2	Fault in Flash Memory
3	Firmware update fault
4	Heater Fault
5	1.4 V Under Voltage Fault
6	1.4 V Over Voltage Fault
7	3.3 V Under Voltage Fault
8	3.3 V Over Voltage Fault
9	5V_I Under Voltage Fault
10	5V_I Over Voltage Fault
11	USB Under Voltage Fault
12	USB Over Voltage Fault
13	24 V Under Voltage Fault
14	24 V Over Voltage Fault
15	Self Test Failure

Example

FALI? A return of '128' would indicate that the 3.3V power supply was under voltage.

FALR? Fault Status Register (Latched)

Query the FALR status register. This register is a latched version of the FALI register. Upon executing a FALR? query, the register is cleared. The meaning of the bits in the FALR register is the same as the FALI register.

Example

FALR? A return of '32768' would indicate that Self Test Failed since last time this register has been read or cleared.

Event Registers

EVNC{?}i{,j} Event Configuration Register

Set (query) Event Relay Configuration Register i to (j). i = 1|2 for Event Relay 1|2. The meaning of the bits in the EVNC registers is the same as the EVNI register. This command sets the Event Relay Configuration page as described in *Events* (page 53). Bits set in this register do not affect behavior of the Event Status registers.

This command will generate an Error 16 (No Option 1) if Option 1 is not installed.

Example

EVNC1,3 This would configure Event Relay 1 to switch to the ON position for either System Fault or No Signal.

EVNE(?){i} Event Enable Register

Set (query) the EVNE enable register {to i}. Bits set in this register cause EVENT (in STB) to be set when the corresponding bit is set in the EVNR register. The meaning of the bits in the EVNE register is the same as the EVNI register.

EVNI? Event Status Register (Immediate)

Query the EVNI register. This register is not latched and reflects the value of the register the instant it was read. See Events in the *Operations Guide* for details on the Event registers. The bits in the EVNI register have the following meaning:

Bit	Meaning
0	System Fault
1	No Signal
2	+Measurement Limit Exceeded
3	-Measurement Limit Exceeded
4	+Pressure 1 Limit Exceeded
5	-Pressure 1 Limit Exceeded
6	+Pressure 2 Limit Exceeded
7	-Pressure 2 Limit Exceeded
8	+Temperature Limit Exceeded
9	- Temperature Limit Exceeded
10-15	reserved

Example

EVNI? A return of '2' would indicate that the BGA244 cannot recover the acoustic signal.

EVNR? Event Status Register (Latched)

Query the EVNR status register. This register is a latched version of the EVNI register. Upon executing a EVNR? query, the register is cleared. The meaning of the bits in the EVNR register is the same as the EVNI register.

Example

EVNR? A return of '4' indicates that the signal exceeded the Measurement Limit since the last read or cleared.

RLYF{?}i{,j} Relay Force

Set (query) the Event Relay (i) Force value {to j}. i = 1 for Event Relay 1 and 2 for Event Relay 2. j can be one of the values in the table. This command is the same as the Event Relay Force functions described in *Events* (page 53).

This command will generate Error 16 (No Option 1) if Option 1 is not installed. If 24 V is not present, you can set the relay position, but the relay is inoperable until 24V is applied. Use the EXPA command to check the 24V power supply.

j	meaning
0	No Force
1	Force Off
2	Force ON

Example

RLYF 1,1 Force Event Relay 1 ON

RLYU?[i] Relay Position

Query the position of Event Relay (i). i = 1 for Event Relay 1 and 2 for Event Relay 2. The return value is 0 for OFF and 1 for ON.

This command will generate an Error 16 (No Option 1) if Option 1 is not installed. It will generate an Error 18 (No 24 V Available) if 24 V is not present.

Example

RLYU?2 A return value of 1 indicates that Event Relay 2 is in the ON position.

Interface Commands

BAUD(?)i{,j} — Set Baud Rate

Set (query) the Baud Rate of interface i {to j}. Parameter i = 0 for RS-232; i = 1 for RS-422. Parameter j (baud rate) is set per the following table:

j	Baud Rate
0	2400
1	4800
2	9600
3	19200
4	38400
5	57600
6	115200

Example

BAUD 0,3 Set RS-232 baud rate to 19200

LERR? — Inspect Error Buffer

Query the last error in the error buffer. Upon executing a LERR? the returned error is removed from the error buffer. See Error Codes on Page 168 for a description. The Error Buffer can store up to 20 errors. If more than 19 errors occur without being queried, the 20th error will be 254 (too many errors), indicating that errors may have been dropped.

UARE(?)i{,j} — Enable Computer Interface

Set (query) computer interface i enable mode {to j}. Parameter i = 0 for RS-232; i = 1 for RS-422. Parameter j = 1 for enabled, otherwise 0.

The RS-422 interface requires Option 1. Enabling the RS-422 interface without Option 1 installed will generate an Error 16 (No Option 1).

Example

UARE 0,0 Disable RS-232

XTRM i{,j,k} — Interface Terminator

Set the interface terminator that is appended to each response to i, j, k. The default terminator is 13, 10, which is a carriage return followed by a line feed.

Measurement and Related Commands

Measurement commands report results from the BGA244. Certain commands require that the BGA244 is in the proper Instrument Mode. If not, an Error 11 (Illegal Mode) will be generated.

Measurements

If an error in a measurement occurs during a query, the unit will return an overload value (9.9E37) to inform the user that there was something wrong with the measurement. The controlling program should identify this and check the BGA0 status register if it occurs. A return value of '0' in the BGA0 status register confirms that a measurement is valid. Any other value indicates there is some problem with the measurement. See *BGA0 Status Register* (page 164) for more information.

Each measurement has its own unit family associated with it. If units are omitted, the selected global unit is used. If units are included with the command, they must be in the correct unit family or an Error 127 (Illegal Units) will be generated.

NSOS?[u] — Normalized Speed of Sound

Query the Normalized Speed of Sound for the current Measurement Mode. If omitted, units default to the global speed units.

Example

NSOS? kph	Query the normalized speed of sound in kilometers per hour
NSOS?	Query the normalized speed of sound in global units

PRES?[u] — Analysis Pressure

Query the Cell Analysis Pressure. If omitted, units default to the global temperature units.

See *Pressure Commands* (page 151) for a list of possible errors that occur with the PRES command.

Example

PRES?	Query the Analysis Pressure in global pressure units

PUDL?[u] — Purity Mode Measurement

Query the Gas Purity Measurement. If omitted, units default to the global ratio units.

This command is valid for Gas Purity Mode. If the command is received when unit is in the Binary Gas or Physical Measurements mode, an Error 11 (Illegal Mode) will be generated.

RATO? i[u] — Binary Gas Ratio Measurement

Query the Binary Gas Ratio of Gas i. i = 1 for Gas 1; i = 2 for Gas 2. If omitted, units default to the global ratio units. The answer is returned in either mole or mass fraction, depending on the concentration type (BCTP).

This command is valid for Binary Gas Analyzer Mode. If the command is received when unit is in the Gas Purity or Physical Measurements mode, an Error 11 (Illegal Mode) will be generated.

Example

RATO? %	Query the Gas Ratio in %.
RATO?	Query the Gas Ratio in the global ratio units.

RAT2? i[u] Binary Gas Ratio 2nd Measurement

Query the 2nd result[1] of the Binary Gas Ratio of Gas i. i = 1 for Gas 1; i = 2 for Gas 2. If omitted, units default to the global ratio units. The answer is returned in either mole or mass fraction, depending on the concentration type (BCTP).

This command is valid for Binary Gas Analyzer Mode. If the command is received when unit is in the Gas Purity or Physical Measurements mode, an Error 11 (Illegal Mode) will be generated.

[1] This is the second concentration (larger value) of a dual concentration measurement. If there isn't a dual concentration it will return the same value as the RATO? command. Refer to *Binary Gas Analyzer* (page 40) for more information.

SSOS?[u] Measured Speed of Sound

Query the Measured Speed of Sound for the current Measurement Mode. If omitted, units default to the global speed units.

Example

SSOS? m/s	Query the Speed of Sound in m/s.

TCEL?[u] Cell Temperature

Query the Cell Temperature. If omitted, units default to the global temperature units.

If an error in a temperature measurement occurs during a query, the unit will return an overload value (9.9E37) to inform the user that there was something wrong with the measurement. The controlling program should identify this and check bits 6, 7 & 8 of the BGA0 status register if it occurs.

Example

TCEL? C	Query the Cell Temperature in °C.

Related Commands

These commands configure measurements and set the screen appearance of the BGA244. Certain commands require that the BGA244 is in the proper Instrument Mode. If not an execution error will be generated (Error 11, Illegal Mode).

AVGE(?){i} Enable Averaging

Set (query) Average Enable {to i}. i = 0 for disabled; i = 1 for enabled.

Example

AVGE1	Enable Averaging

AVGN(?){i} Number of Averages

Set (query) the number of spectrums to be averaged {to i}. i = 2 - 1000

Example

AVGN20	Set the number of averages to 20

BCTP{?}{i} Binary Concentration Type

Set (query) the Binary Concentration Type {to i}. i = 1 for mole fraction; i = 2 for mass fraction.

MSMD(?)i Instrument Mode

Set (query) the Instrument Mode to i. The value of i is determined from the following table. Note that some measurements depend on the Instrument Mode and are only valid for that particular mode.

i	meaning
1	Binary Gas Analyzer
2	Gas Purity Analyzer
3	Physical Measurements

Example

MSMD3	Set the Instrument Mode to Physical Measurements.
MSMD?	A return value of 1 indicated the BGA244 is in the Binary Gas mode.

RELH REL to 100%

Set the REL value to so the measurement reads 100% (or 1,000,000 ppm or 1.0 fraction).

This command is valid for Binary Gas Mode. If the command is received when unit is in the Gas Purity or Physical Measurements mode, an Error 11 (Illegal Mode) will be generated.

RELM(?) REL Mode

Set (query) the REL Mode {to i}. i = 0 for no REL; i = 1 for REL.

This command is valid for Binary Gas and Gas Purity Modes. If the command is received when unit is in the Physical Measurements mode, an Error 11 (Illegal Mode) will be generated.

Example

RELM1 Set REL Mode.

RELV(?){r}[u] REL Value

Set (query) the REL value {to r}. If omitted, units default to the global ratio units.

This command is valid for Binary Gas and Gas Purity Modes. If the command is received when unit is in the Physical Measurements mode, an Error 11 (Illegal Mode) will be generated.

Example

RELV? Query the present REL value in global ratio units.

RELZ REL to Zero

Set the REL value to so the measured value reads 0% (or 0ppm, 0 fraction).

This command is valid for Binary Gas and Gas Purity Modes. If the command is received when unit is in the Physical Measurements mode, an Error 11 (Illegal Mode) will be generated.

Example

RELZ REL the present measurement to 0% (or 0ppm, 0 fraction).

RUNM(?){i} Run Mode

Set (query) the Run Mode {to i}. i = 0 for STOP; i = 1 for RUN.

Example

RUNM0 Set the BGA244 to STOP.

SETT? Averaged Measurement Settled

Query the Measurement Settled status. Returns 0 for no averaging or average not settled. Returns 1 for average settled.

Limits

Limit commands configure the upper and lower limits for the six measurements that can have limits. See the *Limits* section for each measurement in the *Chapter 3: Operations Guide* for more details on their specific Limits.

Each measurement has its own unit family associated with it. If units are omitted, the selected global unit is used. If units are included with the command, they must be in the correct unit family or an Error 127 (Illegal Units) will be generated.

The table below lists the measurement ID, types and their associated units.

ID	Measurement	Unit Family
1	Binary Measurement	'r' (ratio)
2	Gas Purity Measurement	'r' (ratio)
3	Physical Measurement	'v' (speed)
4	Pressure Meter 1	'p' (pressure)
5	Pressure Meter 2	'p' (pressure)
6	Temperature	't' (temperature)

LIME(?)i,j{,k} Limit Enable

Set (query) the enable state of the selected limit type {to k}. Parameter i is the Measurement ID. Parameter j = 1|2 for Upper|Lower limits. Parameter k = 0 for disabled; k = 1 for enabled.

Example

LIME 1,2,1	Enable the Binary Gas Analyzer lower limit
LIME?4,1	Query the enable mode for the Pressure Meter 1 upper limit

LIMH(?)i{,d}[u] Limit Hysteresis

Set (query) the hysteresis value of the selected limit type {to d}. Parameter i is the Measurement ID. Parameter d is a floating point value in units of the associated measurement. If omitted, units default to the Measurement global units.

Example

LIMH 1,3%	Set the Binary Gas Analyzer hysteresis to 3%
LIMH 6,5	Set the Temperature hysteresis to 5 using the global temp units
LIMH?4,Pa	Query the Pressure Meter 1 hysteresis value in Pascal

LIMM(?)i,j{,d}[u] Meter Scale

Set (query) the meter scale value of the selected measurement {to d}. Parameter i is the Measurement ID. Parameter j = 1|2 for Upper|Lower scale. Parameter d is a floating point value in units of the associated measurement. If omitted, units default to the Measurement global units.

The LIMM command is not valid for the Physical Measurement Mode. An Error 11 (Illegal Mode) will be generated for i = 3.

Example

LIMM 2,1,5%	Set the Gas Purity Analyzer meter scale upper value to +5%
LIMM 4,2,25	Set the Press Meter 1 lower scale to 25 global pressure units
LIMM?1,2ppm	Query the Binary Gas Analyzer lower scale value in ppm

LIMS?i Limit State

Query the state of the selected limit type. Parameter i is the Measurement ID. Returns the following:

0	within limits
1	below limit
2	above limit

Example

LIMS? 1	Query the limit state for the Binary Gas Analyzer mode

LIMT(?)i,j{,d}[u] Limit Trip Value

Set (query) the limit trip value of the selected measurement {to d}. Parameter i is the Measurement ID. Parameter j = 1|2 for Upper|Lower limits. Parameter d is a floating point value in units of the associated measurement. If omitted, units default to the Measurement global units.

Example

LIMT 1,1,60%	Set the Binary Gas Analyzer upper limit value to 60%
LIMT 6,2,10C	Set the Temperature lower limit upper value to 10°C
LIMT?4,2	Query Pressure Meter 1 lower limit value in global units.

Configuration Commands

Configuration commands set the BGA244 to make measurements. Some commands may set parameters that are not currently relevant depending on the unit's operating configuration. If so the newly set parameters will be applied when the configuration is changed to make them relevant.

Example
The instrument is in Binary Gas mode and the gas selection is changed for Gas Purity. The gas selection for the Gas Purity has no effect on Binary Gas measurements. However if the measurement mode is changed to Gas Purity, the new selection will be used for those measurements.

Commands that require an installed option that is not present will generate an execution Error 16 (No Option 1 Installed).

Gas Selection Commands

Gases from either the Factory Gas table or User Gas table can be set over the remote interface.

Gases from the Factory Gas Table are selected by their CAS numbers only (CAS#). The CAS# is a string and must include the dashes. The CAS# of a gas can be found online using Google, Wikipedia or in *Appendix A*, which lists all supported gases and their CAS#'s. The preferred gas name will be displayed on the Home page when the gas is set over the remote interface. If an invalid CAS# is set, an Error 26 (Invalid Gas) will be generated.

Gases from the User Gas table are selected by the string "USER-*i* "where i is the User Gas table index number of the gas (1-99). See *User Gases* (page 113) for details on entering User gases. The gas name will be displayed on the Home page as "User/*name*", where *name* is the User table gas name. If an invalid User Gas value is set, an Error 26 (Invalid Gas) will be generated.

GASB(?)i{,s} Set Binary Analyzer Gas

Set (query) Gas i for the Binary Gas Analyzer {to s}. Parameter i is 1 for Gas 1 and 2 for Gas 2.

's' is a string that identifies the gas. This can be the CAS# or the User gas number.

Example

GASB 1, 7440-37-1	Set Gas 1 to 7440-37-1 (argon)
GASB?2	A return of 7727-37-9 indicates that gas 2 is set to nitrogen.

GASH(?){,s} Set Physical Measurements Gas

Set (query) the Gas for Physical Measurements {to s}.

's' is a string that identifies the gas. This can be the CAS#, the User gas number or 'NONE' for GAS=NONE.

Example

GASH USER-1 Set the Physical Measurements gas to User gas 1

GASP(?){,s} Set Purity Analyzer Gas

Set (query) the Gas for the Purity Analyzer {to s}.

's' is a string that identifies the gas. This can be the CAS#, the User gas number or 'NONE' for GAS=NONE.

Example

GASP 7727-37-9 Set Gas Purity gas to 7727-37-9 (nitrogen)

PURS{?}{v}[u] Purity Mode User Speed of Sound

Set (query) the Gas Purity User Speed of Sound when GAS=NONE {to v}. If omitted, units default to the global speed units.

Example

PURS 320 Set the Reference Speed of Sound to 320 in global speed units
PURS?mph Query the Reference Speed of Sound in miles per hour

SWAP Swap Binary Gases

Swap Gas 1 and Gas 2. No return. This command only operates on the Binary Gas Analyzer. An Error 26 (Invalid Gas) will be generated in either Gas 1 or Gas 2 is not specified.

Heater Commands

The Heaters only operate if the Industrial Control Option (Option 1) is installed. These commands will generate an Error 16 (No Option 1) if Option 1 is not installed.

Note that even if the 24V power supply is not present, all Heater parameters can be set even though the heaters will not operate. Use the HEST command to see if the heater is operational or the EXPA command to confirm that the 24 V power supply is present.

Bit 1 of the BGA1 status register will report if the Block Heater is actively regulating the temperature.

BLTM?[u] — **Endplate Temperature**

Query the End Plate Temperature. Returns the endplate temperature. If omitted, units default to the global temperature units.

HEDG(?){i} — **Degas Heater Enable**

Set (query) the Degas Heater Enable Mode {to i}. i = 0 for disabled; i = 1 for enabled.

Example

HEDG 1	Enable the Degas Heater.

HEEN(?){i} — **Block Heater Enable**

Set (query) the Block Heater Enable Mode {to i}. i = 0 for disabled; i = 1 for enabled. Note that enabling the Block Heater will turn the heater only if 24 V is present. Use the HEST command to confirm that the heater is actually on.

Example

HEEN 1	Enable the Block Heater

HEIL(?){d} — **Maximum Heater Current**

Set (query) the Maximum Heater Current {to d} in amps.

Example

HEIL?	Query the maximum heater current in amps

HEPW? — **Heater Power**

Query the Block Heater Power. Return value is in watts (float).

Example

HEPW?	A return value of 10 indicates the heater is delivering 10 watts of power to the BGA244 block

---

HEST? — **Block Heater Status**

Query the Block Heater Status. Returns 1 for heater on, otherwise 0

HETM(?){d} **Block Heater Temperature**

Set (query) the Block Heater Temperature {to d} in °C.

Example

HETM 50 Set the Block Heater Temperature to 50 °C

Pressure Commands

There are two different methods used to enter pressure information: the value can be directly entered or a pressure transducer can be interfaced using one of the Analog Inputs. Direct entry can always be used regardless of options or external power supplies.

The analog inputs can be used to interface to a pressure transducer if the Industrial Control Option (Option 1) is installed. These commands will generate an Error 16 (No Option 1) if Option 1 is not installed.

Note that even if the 24V power supply is not present, all Pressure Meter parameters can be set, even though they will not operate. Use the EXPA command to confirm that the 24 V power supply is present. If you attempt to query the pressure (PRRD or PRES*) when the 24V supply is not available, an Error 18 (No 24V Available) will be generated.

If an analog over or under range occurs during a pressure query (PRRD[1] or PRES), an overload value (9.9E37) will be returned to inform the user that there was something wrong with the measurement. The controlling program should identify this and check the BGA0 and Analog status registers if it occurs. See *Instrument Status Registers* (page 164) for more information.

[1] if Analog In 1 or 2 are configured as pressure gauges

PMAX(?)i{,p}[u] — **Pressure Gauge Scale Maximum**

Set (query) Pressure Gauge scale maximum {to p}. Parameter i = 1|2 for Pressure Gauge 1|2. If omitted, units default to the global pressure unit.

Example

PMAX 1,100psi Set the Scale Maximum for Pressure Gauge 1 to 100 psi

---

PMIN(?)i{,p}[u] — **Pressure Gauge Scale Minimum**

Set (query) Pressure Gauge scale minimum {to p}. Parameter i = 1|2 for Pressure Gauge 1|2. If omitted, units default to the global pressure unit.

Example

PMIN 1,0psi Set the Scale Minimum for Pressure Gauge 1 to 0 psi
PMIN?2 Query the Scale Minimum for Pressure Gauge 2 in global units

---

PRAC(?){i} — **Select Analysis Pressure Source**

Set (query) the pressure analysis source {to i}. i is set per the following table. If the selected source is not configured as a pressure gauge, an Error 23 (Illegal Gauge) will be generated.

Value	Pressure Analysis Source
1	Analog Input 1
2	Analog Input 2
3	User Entered

Example

PRAC 1	Set the Pressure Analysis Source to Analog Input 1
PRAC?	A return value of 3 indicates User Entered pressure is selected.

PRAM(?){p}[u] Set Atmospheric Pressure

Set (query) the Ambient Atmospheric Pressure {to p}. If omitted, units default to the global pressure unit.

Example

PRAM 14.7 psi	Set the Atmospheric Pressure to 14.7 psi
PRAM? torr	Query the Atmospheric Pressure in torr

PREN(?)i{,j} Pressure Gauge Enable

Set (query) the Pressure Gauge enable mode. i = 1|2 for Pressure Gauge 1|2. Parameter j = 0 for disabled; j = 1 for enabled.

Example

PREN 1,1	Enable Pressure Gauge 1
PREN? 2	Query if Pressure Gauge 2 is enabled

PRES?[u] Analysis Pressure

Query the Cell Analysis Pressure. If omitted, units default to the global pressure units.

Example

PRES?	Query the Analysis Pressure in global pressure units

PRRD?i[u] Pressure Gauge Reading

Query the pressure of analog pressure gauge i. i is 1|2 for Pressure Gauge 1|2. If omitted, units default to the global pressure units. If the selected source is not configured as a pressure gauge, an Error 23 (Illegal Gauge) will be generated.

Example

PRRD?1 psi	Query the value of Pressure Gauge 1 in psi

PRSU(?)i{,j} Pressure Measurement Scale Units

Set (query) pressure measurement I scale units {to j}. Parameter j = 0 for absolute units; j = 1 for gauge units. Parameter i is set per the following table.

i	Pressure Measurement
0	User Entered
1	Analog Input 1
2	Analog Input 2

Example

PRSU 1,0	Set the Pressure Gauge 1 to absolute pressure
PRSU? 0	Query User Pressure scale units

PUSR(?){p}[u] User Cell Pressure

Set (query) the User Pressure. If omitted, units default to the global pressure units.

Example

PUSR 20psi Set the User Pressure to 20 psi

Analog I/O Commands

The Analog Inputs and Outputs are part of the Industrial Control Option (Option 1). These commands will generate an Error 16 (No Option 1) if Option 1 is not installed.

Some Analog I/O commands may set parameters that are not currently relevant depending on the unit's configuration. The newly set parameters will be applied when the configuration is changed to make them relevant.

Even if the 24V power supply is not present, all Analog I/O parameters can be set although they will not operate. Use the EXPA command to confirm that the 24 V power supply is present. The following command will generate an Error 18 (No 24V Available) if the 24V power supply is not present: AIRE, MOMA and AOMA.

Measure Analog Output Commands

The Measure Output is linked to the active Measurement Mode. See *Measure Output* (page 80) for more details.

Note that although the Measure Out is linked to the current Measurement Mode, any of the Measure Out parameters can be set at any time.

A parameter ID is used to specify the Measurement Mode for some commands. Each measurement has its own unit family associated with it. If units are omitted, the current global unit is used. If units are included with the command, they must be in the correct unit family or an Error 127 (Illegal Units) will be generated. The table below lists the measurement ID, types and their associated units.

ID	Measurement	Unit Family
1	Binary Measurement	'r' (ratio)
2	Gas Purity Measurement	'r' (ratio)
3	Physical Measurement	'v' (speed)

MOCN(?){i} Measure Out Concentration

Set (query) the Measure Out Binary Gas concentration type {to i}. Parameter i = 1 for 1st solution; i = 2 for 2nd solution.

This command is only active for Binary Gas mode. Refer to *Details* (page 42) for more information description.

MOEN(?){i} Measure Out Enable

Set (query) the Measure Out enable mode. Parameter i = 0 for disabled; i = 1 for enabled.

Example

MOEN 1 Enable Measure Out

MOMN(?)i{,d}[u] Measure Out Scale Min

Set (query) the Measure Out Scale Min of Measurement Mode i {to d}. Parameter i is the Measurement ID shown at the beginning of this section.

MOMX(?)i{,d}[u] Measure Out Scale Max

Set (query) the Measure Out Scale Max of Measurement Mode i {to d}. Parameter i is the Measurement ID shown at the beginning of this section.

Example

MOMX 1,0%	Set the Measure Out Scale Max of the BGA to 0%
MOMX 2,+10	Set the Measure Out Scale Max of the Purity Analyzer to +10%
MOMX?2	Query the Measure Out Scale Max of Physical Measurements in global units

MOTY(?){i} Measure Out Type

Set (query) the Measure Out type {to i}. Parameter i selects one of the following output types.

i	Output Type
1	0 – 5 V
2	0 – 10 V
3	4 – 20 mA

Example

MOTY 2	Set Measure Out to 0 - 10V

MOVA? Measure Out Value

Query the present Measure Out value. The return value is in volts or amps determined by the Measure Output Type.

An Error 18 (No 24V Available) will be generated if the 24V power supply is not available. An Error 24 (Output Error) will be generated if the output is disabled.

If an over temperature or current alert is active the command will return an overload value (9.9E37). The controlling program should identify this and check the Analog status register if it occurs. Refer to *Instrument Status Registers* (page 164) for more information.

Analog Output Commands

The Analog Outputs can be linked to user values or one of several different measurements. See Analog Outputs (page 79) for more details.

Note that although the Analog Out is only linked to the selected measurement, any of the Analog Out parameters can be set at any time.

A parameter ID is used to specify the Measurement for some commands. Each measurement has its own unit family associated with it. If units are omitted, the selected global unit is used. If units are included with the command, they must be in the correct unit family or an Error 127 (Illegal Units) will be generated. The table below lists the measurement ID, types and their associated units.

ID	Measurement	Unit Family
1	Speed of Sound	'v' (ratio)
2	Normalized Speed of Sound	'v' (ratio)
3	Cell Temperature	't' (speed)
4	Pressure Meter 1	'p' (pressure)
5	Pressure Meter 2	'p' (pressure)
6	User Setting	none

AOEN(?)i{,j} Analog Out Enable

Set (query) the Measure Out enable mode. Parameter i = 1|2 for Analog Out 1|2. Parameter j is 0 for disabled; i is 1 for enabled.

Example

AOEN 1,1 Enable Analog Out 1

AOMN(?)i,j{,d}[u] Analog Out Scale Min

Set (query) Analog Out i, Measurement j, Scale Min {to d}. Parameter i = 1|2 for Analog Out 1|2. Parameter j is the Measurement ID shown at the beginning of this section.

AOMX(?)i,j{,d}[u] Analog Out Scale Max

Set (query) Analog Out i, Measurement j, Scale Max {to d}. Parameter i = 1|2 for Analog Out 1|2. Parameter j is the Measurement ID shown at the beginning of this section.

Example

AOMX 1,4,10Pa Set Analog Out 1, Pressure Meter 1, Scale Max to 0 Pascal
AOMX 2,10C Set Analog Out 1, Cell Temperature, Scale Max to 10 °C
AOMX?2 Query the Measure Out Scale Max of Physical Measurements in global units

AOSE(?)i{,j} Analog Out Measure Setting

Set (query) the Analog Out i type {to j}. Parameter i = 1|2 for Analog Out 1|2. Parameter j is the Measurement ID shown at the beginning of this section.

Example

AOSE 1,3 Set Analog Out 1 to Cell Temperature

AOTY(?)i{,j} Analog Out Type

Set (query) the Analog Out i type {to j}. Parameter i = 1|2 for Analog Out 1|2. Parameter j selects one of the following output types:

j	Output Type
1	0 – 5 V
2	0 – 10 V
3	4 – 20 mA

Example

AOTY1,3 Set Analog Out 1 to 40 – 20 mA

AOUS(?)i{,d} Analog Out User Setting

Set (query) Analog Out i User setting {to d} in volts or amps. Parameter i = 1|2 for Analog Out 1|2.

Example

AOUS 2,9.00 Set Analog Out 2 to 9.00 volts (for Analog Out 2 set to volts)
AOUS 1,20e-3 Set Analog Out 1 to 20 mA (for Analog Out 1 set to current)

AOVA?i Analog Out Value

Query the present Analog Out i. The returned value is in volts or amps determined by the Analog Out Type. Parameter i = 1|2 for Analog Out 1|2.

An Error 18 (No 24V Available) will be generated if the 24V power supply is not available. An Error 24 (Output Error) will be generated if the output is disabled.

If an over temperature or current alert is active the command will return an overload value (9.9E37). The controlling program should identify this and check the Analog Status Register if it occurs. Refer to *Instrument Status Registers* (page 164) for more information

Analog Inputs Commands

Analog Inputs can be read directly or configured as a pressure meter. Refer to *Pressure Commands* (page 151) and *Analog Inputs* (page 78) for more details.

Some Analog In commands set parameters that are not currently relevant depending on the unit's configuration. These parameters will be applied when the configuration is changed to make them relevant.

AILP(?)i{,d} Analog Loop Power Voltage

Set (query) the Analog Input i Loop Power Voltage {to d} in volts. i = 1|2 for Analog Input 1|2.

Example

AILP 1,9.0	Set the Loop Power Voltage of Analog Input 1 to 9.0 V.
AILP? 2	Query the Loop Power Voltage of Analog Input 2.

AINE(?)i{,j} Analog Input Enable

Set (query) the Analog Input i Enable Mode {to j}. Parameter i = 1|2 for Analog Input 1|2. Parameter j = 0 for disabled; j = 1 for enabled.

Example

AINE 1,1 Enable Analog Input 1

AIRE?i Read Analog Input

Query Analog Input i. The returned value is in volts or amps determined by the Analog In Type. i = 1|2 for Analog Input 1|2.

An Error 18 (No 24V Available) will be generated if the 24V power supply is not available. An Error 25 (Input Error) will be generated if the input is disabled.

The controlling program should check the Analog status register to ensure that no voltage or current alerts are active when reading the Analog Input to determine that the reading is valid. See *Instrument Status Registers* (page 164) for more information.

Example

AIRE? 2 Query Analog Input 2.

AITY(?)i{,j} **Analog Input Type**

Set (query) the Analog Input I type {to j}. Parameter i = 1|2 for Analog Input 1|2. Parameter j selects one of the following input configurations.

Note that there are two input configurations that are query only. These indicate that the current input is in its overload protection state. See Analog Inputs (page 78) for details.

j	Input Configuration
1	Voltage
2	Current
3	Current w/ Bias
4 [1]	Current (overload protection)
5 [1]	Current w/ Bias (overload protection)

[1] Query only values

Example

AITY 1,1	Set Analog Input 1 to Current
AITY? 2	A return of 4 would indicate that Analog Input 2 was set to current and in the overload protection state.

Miscellaneous Commands

These commands control functions that aren't described elsewhere.

BAKL(?){i} **Backlight**

Set (query) the Display Backlight Intensity {to i}. Parameter i is varies from 1 – 10, where 1 is the dimmest and 10 the brightest.

Example

BAKL 5 Set the Backlight Intensity to 50%.

BLTM?[u] **Endplate Temperature**

Query the End Plate Temperature. If omitted, units default to the global temperature units.

Example

BLTM? C Returns the temperature of the End Plates in °C

DSPO(?){i} **Display Orientation**

Set (query) the Display Orientation {to i}. Parameter i is defined per the following table. The orientation is viewed relative to the front panel name and logo.

i	Display Orientation
0	+90°
1	0°
2	-90°
3	180°

Example

DSPO 1 Rotate the Display to 0°

ERAS i **Erase Stored Setting**

Erase instrument setting at location i. The parameter i may range from 1 to 20.

Example

ERAS 3 Erase the setting at location 3.

EXPA? **External Power Available?**

Query if External 24 V power is available. Returns 1 if available, otherwise 0.

Example

EXPA? A Return of 1 indicates +24V is present.

MUTE(?){i} **Keyclick Mute**

Set (query) the Key Click Mute {to i}. Parameter i = 0 for Mute off and 1 for Mute on (no sound).

Example
MUTE 0 Turn the Key Click off.

OPTN? i Installed Options

Query whether Option i is installed. Returns 1 if the option is installed, otherwise 0. The parameter i identifies the option.

i	Option
1	Industrial Control Interface
2	No Display

PASE(?){i} Password Enable

Set (query) the Password Lock mode {to i}. Parameter i = 1 for enabled, i = 0 for disabled.

Example
PASE 1 Set Password lock

PASL? Password Locked Status

Query the Password Locked status. Returns 0 for unlocked, 1 for locked.

PASS(?){i} Set Password

Set the Password to i. Parameter i must be between 0 and 9999.

Example
PASS 1234 Set Password to '1234'

PCTM?[u] PCB Temperature

Query the PCB Temperature. If omitted, units default to the global temperature units.

Example
PCTM? Returns the temperature of the PCB in global temperature units

UNFA(?)i{,s} Global Units

Set (query) Global Unit i {to s}. Parameter i and the allowable strings for 's' are listed below.

i	unit type	allowed unit strings
1	Ratio	'%', 'ppm', 'frac'
2	Speed	'm/s', 'kph', 'mph'
3	Temperature	'C', 'K', 'F'
4	pressure	'psi', 'atm', 'bar', 'Pa', 'mmHg', 'torr'

Example
UNFA 1,% Set the Global Ratio Units to %
UNFA?4 A return of 'Pa' indicates the Global Pressure units are Pascal.

VOLT? i **External Power Voltage**

Query Power Supply Voltage i. Returns voltage in volts (float). Parameter i = 1 for USB supply, i = 2 for 24 V Supply.

Status Byte Definitions

The BGA244 reports on its status by means of several status registers. These include the serial poll status byte, the standard event status register (*ESR) and several additional instrument status registers (INSRs). These read-only registers record the occurrence of defined events inside the unit. If the event occurs, the corresponding bit is set to one. Bits in the status registers are latched[1]. Once an event bit is set, subsequent state changes do not clear the bit. All bits are cleared when the registers are queried, with a *ESR?, for example. The bits are also cleared with the clear status command, *CLS. The bits are not cleared, however, with an instrument reset (*RST) or a device clear (break signal).

Each of the unit's event status registers has an associated enable register. The enable registers control the reporting of events in the serial poll status byte (*STB). If a bit in the event status register is set and its corresponding bit in the enable register is set, then the summary bit in the serial poll status byte (*STB) will be set. The enable registers are readable and writable. Reading the enable registers or clearing the status registers does not clear the enable registers. Bits in the enable registers must be set or cleared explicitly. To set bits in the enable registers, write an integer value equal to the binary weighted sum of the bits you wish to set.

The serial poll status byte (*STB) also has an associated enable register called the service request enable register (*SRE). This register functions in a similar manner to the other enable registers, except that it controls the setting of the master summary bit (bit 6) of the serial poll status byte.

[1] Besides the latched INSRs, there are unlatched (or immediate) copies of some of the status registers that reflect the value of the bits the instant the register was read. Having both the latched and unlatched copies of the registers can make it easier to determine the state of the BGA244.

Power On Behavior of Status Registers

The PSC flag determines the behavior of the *SRE and *ESE mask registers upon power on. If the value of the flag is 0 their values are loaded from non-volatile memory. If the value of the flag is 1 both registers are cleared upon power on.

All other enable registers are cleared at power on.

Serial Poll Status Byte

Bit	Name	Meaning
0	BG0B	An unmasked bit in the BGA0 status register (BG0R) has been set.
1	BG1B	An unmasked bit in the BGA1 status register (BG1R) has been set.
2	FALB	An unmasked bit in the FAULT status register (FALR) has been set.
3	ANAB	An unmasked bit in the ANALOG status register (ANAR) has been set.
4	MAV	The interface output buffer is non-empty
5	ESB	An unmasked bit in the standard event status register (*ESR) has been set.
6	MSS	Master summary bit. Indicates that the instrument is requesting service because an unmasked bit in this register has been set.
7	EVNB	An unmasked bit in the EVENT status register (EVNR) has been set.

The serial poll status byte may be queried with the *STB? command.

Standard Event Status Register

Bit	Name	Meaning
0	OPC	Operation complete. All previous commands have completed. See command *OPC.
1	Reserved	
2	QYE	Query error occurred.
3	DDE	Unused.
4	EXE	Execution error. A command failed to execute correctly because a parameter was invalid.
5	CME	Command error. The parser detected a syntax error.
6	Reserved	
7	PON	Power on. The unit has been power cycled.

The standard event status register may be queried with the *ESR? command. The standard event status enable register (*ESE) may be used to control the setting of the ESB summary bit in the serial poll status byte.

Instrument Status Register Model

The BGA244 has five groups of Instrument Status Registers (INSRs). Each group contains three separate 16 bit registers. The first register contains a latched copy of each bit. The second register is an enable register for the first register and is used as a mask for the summary bits in the Status Byte register. The third register contains the unlatched version of each bit. The unlatched (or immediate) register shows the value of the bits at the instant it was read. Each Status Register is described below, together with the page in the *Operations Guide* that refers to specific meaning of each bit.

BGA Status Register 0

Bit	Meaning	See
0	Dual Concentration (BGA Mode only)	Page 42
1	Degas Heater on	Page 76
2	Measurement is stopped	Page 56
3	Measurement is below allowable range	Page 49
4	Measurement is above allowable range	Page 49
5	No Signal	Page 49
6	> 5 °C mismatch on temperature measurements	Page 84
7	Cell Temperature < 0 °C	Page 84
8	Cell Temperature > 70 °C	Page 84
9	Bad Analysis Pressure Reading	Page 63
10	Condensation Warning	Page 50
11-14	reserved	
15	Summary bit for Fault Register (FALR)	Page 166

BGA Status Register 1

Bit	Meaning	See
0	reserved	
1	Heater is not Regulating	Page 75
2	Measurement Meter Limits exceeded	Page 52
3	Pressure Meter 1 Limits exceeded	Page 63
4	Pressure Meter 2 Limits exceeded	Page 63
5	Temperature Meter Limits exceeded	Page 64
6	USB Voltage is over range	Page 85
7	USB Voltage is under range	Page 85
8	+24 V is over range	Page 85
9	reserved	
10	REL mode active	Page 59
11	reserved	
12	Password Lock	Page 88
13	Average Not Settled (0=settled, 1= not settled)	Page 72
14-15	reserved	

Fault Status Register

Bit	Meaning	See
0	Cell Under Temperature fault	Page 83
1	Cell Over Temperature fault	Page 83
2	Fault in Flash Memory	Page 83
3	Firmware update fault	Page 83
4	Heater Fault	Page 83
5	1.4 V Under Voltage Fault	Page 83
6	1.4 V Over Voltage Fault	Page 83
7	3.3 V Under Voltage Fault	Page 83
8	3.3 V Over Voltage Fault	Page 83
9	5V_I Under Voltage Fault	Page 83
10	5V_I Over Voltage Fault	Page 83
11	USB Under Voltage Fault	Page 83
12	USB Over Voltage Fault	Page 83
13	24 V Under Voltage Fault	Page 83
14	24 V Over Voltage Fault	Page 83
15	Self Test Failure	Page 86

Analog Status Register

Bit	Meaning	See
0	Measure Out Current Alert	Page 79
1	Measure Out Temperature Alert	Page 79
2	Output 1 Current Alert	Page 79
3	Output 1 Temperature Alert	Page 79
4	Output 2 Current Alert	Page 79
5	Output 2 Temperature Alert	Page 79
6	Input 1 Over Current Alert	Page 78
7	Input 1 Under Current Alert	Page 78
8	Input 1 Over Voltage	Page 78
9	Input 1 Under Voltage	Page 78
10	Input 2 Over Current	Page 78
11	Input 2 Under Current	Page 78
12	Input 2 Over Voltage	Page 78
13	Input 2 Under Voltage	Page 78
14	Loop Power Alert	Page 78
15	reserved	

Event Status Register

The Event Registers operate independently from the Event Relay configuration in the unit. A single register group (latched, enable and immediate) contains all of the event condition. These registers have no effect on the Event Relay configuration. User code should be used to determine the appropriate actions based on the event conditions.

Use the EVNC command to set the Event Relay Configuration. Refer to *Events* (page 53) for details on the specific conditions for items in the Event register. Use the RLYF command to force the relays on or off.

Event Status Register

Bit	Meaning	See
0	System Fault	Page 54
1	No Signal	Page 54
2	+Measurement Limit Exceeded	Page 54
3	-Measurement Limit Exceeded	Page 54
4	+Pressure 1 Limit Exceeded	Page 54
5	-Pressure 1 Limit Exceeded	Page 54
6	+Pressure 2 Limit Exceeded	Page 54
7	-Pressure 2 Limit Exceeded	Page 54
8	+Temperature Limit Exceeded	Page 54
9	- Temperature Limit Exceeded	Page 54
10-15	reserved	

Error Codes

The instrument contains an error buffer that may store up to 20 error codes associated with errors encountered during power-on self tests, command parsing, or command execution. The ERR LED will flash when a remote command fails for any reason. The errors in the buffer may be read one by one by executing successive LERR? commands. The meaning of each of the error codes is described below.

Execution Errors

0 No Error

No more errors left in the queue.

10 Illegal Value

A parameter was out of range.

11 Illegal Mode

The action is illegal in the current mode. This would happen if the user tries to RELZ when the Instrument Mode is set to Physical Measurements.

12 Flash Read Error

There was an error when attempting to read flash memory.

13 Recall Failed

The recall of instrument settings from nonvolatile storage failed because its instrument settings were invalid.

14 Flash Write Error

There was an error when attempting to write flash memory.

15 Flash Erase Error

There was an error when attempting to erase flash memory.

16 No Option 1

The requested action failed because the Industrial Control option (Option 1) is not installed.

17 No Option 2

The requested action failed because the No Display option (Option 2) is not installed.

18 No 24V Available

The requested action failed because +24V power supply was not available.

19 Cal Error

The requested action failed because of an error in the calibration data.

20 Firmware Error

The requested action failed because of an error in the Firmware Update.

21 Time Out Error

The requested action failed because of a Time Out error.

22 Binary Stream Error

The requested action failed because of an error in the binary stream.

23 Illegal Gauge

The requested action failed because the Analog Input is not defined as a pressure gauge.

24 Output Error

The requested action failed because the Analog Output is disabled.

25 Input Error

The requested action failed because the Analog Input is disabled.

26 Invalid Gas

The requested action failed because of an improperly specified gas.

27 Not allowed

The requested action failed because another operation blocked it.

Query Errors

30 Lost Data

Data in the output buffer was lost. This occurs if the output buffer overflows or if a communications error occurs and data in output buffer is discarded.

Parsing or Command Errors

110 Illegal Command

The command syntax used was illegal. A command is normally a sequence of four letters, or a '*' followed by three letters.

111 Undefined Command

The specified command does not exist.

112 Illegal Query

The specified command does not permit queries

113 Illegal Set

The specified command can only be queried.

114 Null Parameter

The parser detected an empty parameter.

115 Extra Parameters

The parser detected more parameters than allowed by the command.

116 Missing Parameters

The parser detected missing parameters required by the command.

117 Parameter Overflow

The buffer for storing parameter values overflowed. This probably indicates a syntax error.

118 Invalid Floating Point Number

The parser expected a floating point number, but was unable to parse it.

120 Invalid Integer

The parser expected an integer, but was unable to parse it.

121 Integer Overflow

A parsed integer was too large to store correctly.

122 Invalid Hexadecimal

The parser expected hexadecimal characters but was unable to parse them.

126 Syntax Error

The parser detected a syntax error in the command.

127 Illegal Units

The units supplied with the command are not allowed.

128 Missing Units

The units required to execute the command were missing.

Communication Errors

170 Communication Error

A communication error was detected. This is reported if the hardware detects a framing, or parity error in the data stream.

171 Over run

The input buffer of the remote interface overflowed. All data in both the input and output buffers will be flushed.

Other Errors

254 Too Many Errors

The error buffer is full. Subsequent errors have been dropped.

Using the USB Drivers

The BGA244 uses an FTDI FT220X USB interface chip. FTDI provides two different types of software drivers to communicate with the interface chip: VCP, a Virtual COM Port and D2XX, a dynamic linked library (DLL). Drivers are available for various versions of Microsoft Windows, Mac OS-X, Linux 2.6 & greater and Android. Some operating systems may not have both drivers available. Detailed information of the drivers and their installation is provided on the FTDI web site: www.ftdichip.com/Drivers.

VCP or Virtual COM Port makes the BGA244 look like an additional COM port available to the computer. Application software can access the BGA244 in the same way as it accesses any standard COM port. This is usually the simplest way to control the BGA244 using the USB port.

The D2XX driver gives access the BGA244 through a DLL. Application software can access the BGA244 through a series of DLL function calls. See the *D2XX Programmer's Guide* on the FTDI web site for a list of available functions. The D2XX driver is a bit more complicated to use, but is faster than the VCP.

Both methods use the remote commands previously described in this chapter to communicate with the BGA244. Be sure that the appropriate driver is installed on any computer that communicates with the BGA244 over USB.

Windows Drivers for the BGA244

If you connect the BGA244 using a computer running Microsoft Windows, it may detect the USB Interface Chip and offer to install two drivers for the device (VCP and D2XX drivers). Depending on the version and configuration, Windows may either automatically install the drivers or prompt you to search for them. If you need to search for them, the drivers are located at the FTDI web site: www.ftdichip.com/Drivers. If there are difficulties installing the driver, see *Appendix E* for details on manually installing them.

Chapter 7: Service

Troubleshooting

Fault Name	Meaning	Action Required
Magnet Fault (from Self-Test)	The magnets used in the acoustic transducer are weak.	Fatal if it persists; Return to SRS
Membrane Fault (from Self-Test)	The membrane in the acoustic transducer is damaged.	Fatal if it persists; Return to SRS
Over Temperature	The temperature sensors are reporting a temperature > 70 °C	Turn off the heaters if they are on.
USB Power under voltage		
+24V under voltage		
Internal supplies under voltage		
SPI ADCs or DACs not working		
CODEC values out of range		

If you are contacting SRS about a problem with your BGA244, please have the following information readily available.

- The unit serial number
- The firmware version number
- A description of the problem
- Any error messages

Calibration

Calibration

Maintenance

Replacement terminal blocks are available from Digikey or other distributors.

Connector	Phoenix Contact p/n	Digikey p/n
C4, C6 (5 pin)	1803604	277-1164-ND
C7 (8 pin)	1803633	277-1167-ND
C8 (6 pin)	1803617	277-1165-ND

Appendix A: Gas Table

Factory Gas Table

The Factory Gas Table contains data for about 500 different gases that are supported by the BGA244. Each entry includes the formula, common name, CAS number, up to two alternate names and physical data about the gas. The gas(es) to be analyzed are chosen on the Setup page (page 57). The individual gas can be selected using any of the names, the chemical formula or the CAS number.

Data on additional gases can be added to the BGA244 using the User Gas Table. See Entering the User Gas Table (page 119) for the procedure on adding new gases to the User Gas Table.

The table below lists all of the gases in the Factory Gas Table, sorted by molecular weight. Each entry contains the preferred name, up to two alternate names, the formula (in Hill notation), the molecular weight and the CAS number.

FACTORY GAS TABLE A1

Preferred Name	Alternate Name 1	Alternate Name 2	Formula	Weight	CAS#
Hydrogen, normal	Normal hydrogen		H2	2.01588	1333-74-0n
Hydrogen, ortho	Ortho hydrogen		H2	2.01588	1333-74-0o
Hydrogen, para	Para hydrogen		H2	2.01588	1333-74-0p
Hydrogen			H2	2.01588	1333-74-0
Helium-3	He-3		He-3	3.01603	14762-55-1
Deuterium hydride			DH	3.022	13983-20-5
Helium	Helium-4		He	4.002602	7440-59-7
Deuterium			D2	4.0282	7782-39-0
Methane	R-50	Carbon tetrahydride	CH4	16.0428	74-82-8
Ammonia	Nitrogen trihydride	NH3	H3N	17.03026	7664-41-7
Water	Dihydrogen Monoxide		H2O	18.01527	7732-18-5
Hydrogen fluoride			HF	20.006	7664-39-3
Heavy Water	Deuterated Water		D2O	20.02751	7789-20-0
Neon			Ne	20.179	7440-01-9
Ethyne	Acetylene		C2H2	26.037	74-86-2
Hydrogen cyanide			CHN	27.025	74-90-8
Diborane	Boroethane	B2H6	H6B2	27.67	19287-45-7
Carbon monoxide	Carbon oxide		CO	28.0101	630-08-0
Nitrogen			N2	28.01348	7727-37-9
Ethylene	Dicarbene	Ethene	C2H4	28.05376	74-85-1
Air, dry			N2-O2-Ar	28.96	132259-10-0
Nitrogen oxide	Nitrogen monoxide	Nitric oxide	NO	30.006	10102-43-9
Formaldehyde			CH2O	30.026	50-00-0
Ethane			C2H6	30.06904	74-84-0
Methanamine	Aminomethane	Methylamine	CH5N	31.057	74-89-5
Oxygen			O2	31.9988	7782-44-7
Methanol	Methyl alcohol		CH4O	32.04216	67-56-1

Preferred Name	Alternate Name 1	Alternate Name 2	Formula	Weight	CAS#
Hydrazine			H4N2	32.045	302-01-2
Fluoromethane	R-41	Methyl fluoride	CH3F	34.033	593-53-3
Hydrogen sulfide			H2S	34.08088	7783-06-4
Hydrogen chloride			HCl	36.461	7647-01-0
Fluorine			F2	37.99681	7782-41-4
Argon			Ar	39.948	7440-37-1
1,2-Propadiene	Allene	Propadiene	C3H5	40.064	463-49-0
1-Propyne	Prop-1-yne	Methyl acetylene	C3H4	40.0639	74-99-7
Acetonitrile			C2H3N	41.052	75-05-8
1-Propene	Prop-1-ene	Propylene	C3H6	42.07974	115-07-1
Cyclopropane	Trimethylene		C3H6	42.081	75-19-4
Ethyleneimine			C2H5N	43.068	151-56-4
Carbon dioxide	R-744	Carbonyl oxide	CO2	44.0098	124-38-9
Dinitrogen monoxide	R-744A	Nitrous oxide	N2O	44.0128	10024-97-2
Acetaldehyde			C2H4O	44.053	75-07-0
Ethylene oxide			C2H4O	44.053	75-21-8
Propane	Dimethylmethane		C3H8	44.09562	74-98-6
Formamide			CH3NO	45.041	75-12-7
N-Methylmethanamine	N,N-Dimethylamine	Dimethylamine	C2H7N	45.084	124-40-3
Ethanamine	Aminoethane	Ethylamine	C2H7N	45.084	75-04-7
Formic acid	Methanoic acid		CH2O2	46.026	64-18-6
Methoxymethane	1,1'-Oxybismethane	Dimethyl ether	C2H6O	46.06844	115-10-6
Ethanol	Ethyl alcohol		C2H6O	46.06844	64-17-5
Methylsilane			CH6Si	46.144	992-94-9
Ozone	Triatomic oxygen		O3	47.998	10028-15-6
Fluoroethane	R-161	Ethyl fluoride	C2H5F	48.06	353-36-6
Methanethiol	Methylsulfide	Methyl mercaptan	CH4S	48.107	74-93-1
Chloromethane	R-40	Methyl chloride	CH3Cl	50.488	74-87-3
Difluoromethane	R-32	methylene fluoride	CH2F2	52.024	75-10-5
Cyanogen			C2N2	52.035	460-19-5
Vinyl acetylene			C4H4	52.075	689-97-4
Acrylonitrile			C3H3N	53.063	107-13-1
1,3-Butadiene	Butadiene		C4H6	54.09	106-99-0
1-Butyne	Ethylacetylene	But-1-yne	C4H6	54.09	107-00-6
Dimethyl acetylene			C4H6	54.09	503-17-3
1,2-Butadiene			C4H6	54.09	590-19-2
1,2-Oxazole	1-oxa-2-azacyclopentadiene	Isoxazole	C3H3NO	55.058	288-14-2
Propionitrile			C3H5N	55.079	107-12-0
Acrolein			C3H4O	56.063	107-02-8
1-Butene	Butylene		C4H8	56.10632	106-98-9
2-Methyl-1-propene	2-Methylpropene	Isobutene	C4H8	56.10632	115-11-7
Cyclobutane	Tetramethylene		C4H8	56.106	287-23-0
(2Z)-2-Butene	cis-2-Butene	Z-2-Butene	C4H8	56.10632	590-18-1
(2E)-2-Butene	E-2-butene	trans-2-Butene	C4H8	56.10632	624-64-6
Methyl Isocyanate			C2H3NO	57.051	624-83-9
Methyl vinyl ether			C3H6O	58.079	107-25-5
Propionaldehyde			C3H6O	58.079	123-38-6
Acetone	dimethyl ketone	2-Propanone	C3H6O	58.07914	67-64-1
Butane	n-Butane		C4H10	58.1222	106-97-8
Isobutane	i-Butane	2-Methylpropane	C4H10	58.1222	75-28-5

Preferred Name	Alternate Name 1	Alternate Name 2	Formula	Weight	CAS#
Acetamide			C2H5NO	59.067	60-35-5
1-Propanamine	1-Aminopropane	n-Propyl Amine	C3H9N	59.11	107-10-8
2-Propaneamine	2-Aminopropane	Isopropyl amine	C3H9N	59.11	75-31-0
N,N-Dimethylmethanamine	Trimethylamine		C3H9N	59.11	75-50-3
Methyl formate	Methyl methanoate		C2H4O2	60.052	107-31-3
Acetic acid			C2H4O2	60.052	64-19-7
carbonyl sulfide	carbon oxide sulfide		COS	60.0751	463-58-1
Methoxyethane	Methyl ethyl ether	Methylethyl ether	C3H8O	60.095	540-67-0
2-Propanol	Isopropyl alcohol	Isopropanol	C3H8O	60.095	67-63-0
1-Propanol	Propyl alcohol	Propan-1-ol	C3H8O	60.095	71-23-8
Ethylenediamine			C2H8N2	60.098	107-15-3
Dimethylsilane			C2H8Si	60.17	1111-74-6
Nitromethane	nitrocarbol		CH3NO2	61.04	75-52-5
Ethylene glycol			C2H6O2	62.068	107-21-1
Ethanethiol	Thioethanol	Ethyl mercaptan	C2H6S	62.134	75-08-1
Methylthiomethane	Thiobismethane	Dimethyl sulfide	C2H6S	62.134	75-18-3
Vinyl chloride			C2H3Cl	62.498	75-01-4
1,1-Difluoroethene	R-1132A	1,1-Difluoroethylene	C2H2F2	64.035	75-38-7
Sulfur dioxide		SO2	O2S	64.0638	7446-09-5
Chloroethane	1-Chloroethane	Ethyl chloride	C2H5Cl	64.514	75-00-3
1,2-Difluoroethane			C2H4F2	66.05	624-72-6
1,1-Difluoroethane	R-152a	Algofrene 67	C2H4F2	66.051	75-37-6
2-Methyl -1-butene-3-yne			C5H6	66.101	78-80-8
1H-Pyrrole	Azole	Pyrrole	C4H5N	67.09	109-97-7
Furan	1,4-Epoxy-1,3-butadiene		C4H4O	68.074	110-00-9
Cyclopentene			C5H8	68.117	142-29-0
3-Methyl-1-butyne			C5H8	68.117	598-23-2
3-Methyl-1,2-butadiene			C5H8	68.117	598-25-4
1-Pentyne	Ethylmethylacetylene	Pent-1-yne	C5H8	68.117	627-19-0
2-Pentyne			C5H8	68.117	627-21-4
Butyronitrile			C4H7N	69.105	109-74-0
Fluoroform	R-23	Trifluoromethane	CHF3	70.01385	75-46-7
1-Pentene	cis-Pentene	Pent-1-ene	C5H10	70.133	109-67-1
Cyclopentane	Pentamethylene		C5H10	70.133	287-92-3
2-Methyl-2-butene	2-Methylbut-2-ene	Amylene	C5H10	70.133	513-35-9
2-Methyl-1-butene			C5H10	70.133	563-46-2
3-Methyl-1-butene	Methylethylethylene	3-Methylbut-1-ene	C5H10	70.134	563-45-1
(2Z)-2-Pentene	cis-2-Pentene	Z-2-Pentene	C5H10	70.134	627-20-3
Chlorine			Cl2	70.906	7782-50-5
Nitrogen trifluoride			F3N	71.019	7783-54-2
Acrylic acid			C3H4O2	72.063	79-10-7
Trimethylaluminium	TMA	Aluminum trimethanide	C3H9Al	72.085	75-24-1
Tetrahydrofuran	Butylene oxide	Diethylene oxide	C4H8O	72.106	109-99-9
Butyraldehyde			C4H8O	72.106	123-72-8
Methylethyl ketone	Butanone	MEK	C4H8O	72.106	78-93-3
Neopentane	Dimethylpropane	2,2-Dimethylpropane	C5H12	72.14878	463-82-1
Pentane	n-Pentane		C5H12	72.14878	109-66-0
Isopentane	2-Methyl butane		C5H12	72.14878	78-78-4
N,N-Dimethyl formamide			C3H7NO	73.094	68-12-2
N-Methyl acetamide			C3H7NO	73.094	79-16-3

Preferred Name	Alternate Name 1	Alternate Name 2	Formula	Weight	CAS#
N-Ethylethanamine	N,N-Diethylamine	Diethylamine	C4H11N	73.137	109-89-7
1-Butanamine			C4H11N	73.138	109-73-9
2-Methyl-1-propanamine	Isopropylmethylamine	Isobutylamine	C4H11N	73.138	78-81-9
Ethyl formate	Ethyl methanoate	Ethyl ester of formic acid	C3H6O2	74.079	109-94-4
Propionic acid			C3H6O2	74.079	79-09-4
Methyl acetate	Methyl ethanoate		C3H6O2	74.079	79-20-9
Methylpropyl ether			C4H10O	74.122	557-17-5
Methylisopropyl ether			C4H10O	74.122	598-53-8
Ethoxyethane	1,1'-Oxybisethane	Diethyl ether	C4H10O	74.122	60-29-7
1-Butanol	Propylmethanol	1-Butyl alcohol	C4H10O	74.122	71-36-3
2-Methyl-2-propanol	ter-Butyl alcohol	tert-Butanol	C4H10O	74.122	75-65-0
2-Butanol	Methyl-2-propanol	sec-Butanol	C4H10O	74.122	78-92-2
2-Methyl-1-propanol	2-Methylpropanol	Isobutanol	C4H10O	74.123	78-83-1
Nitroethane			C2H5NO2	75.067	79-24-3
1,2-Propylene glycol			C3H8O2	76.094	57-55-6
Carbon disulfide			CS2	76.141	75-15-0
Propyl mercaptan			C3H8S	76.161	107-03-9
Methylethyl sulfide			C3H8S	76.161	624-89-5
2-Propyl mercaptan			C3H8S	76.161	75-33-2
Germane			GeH4	76.642	7782-65-2
Arsine	AsH3		H3As	77.945	7784-42-1
Benzene	1,3,5-Cyclohexatriene	Cyclohex-1,3,5-triene	C6H6	78.11184	71-43-2
Dimethyl sulfoxide			C2H6OS	78.133	67-68-5
1-Chloropropane	Propyl chloride		C3H7Cl	78.541	540-54-5
2-Chloropropane			C3H7Cl	78.541	75-29-6
Pyridine	Azabenzene		C5H5N	79.101	110-86-1
Sulfur trioxide			O3S	80.063	7446-11-9
Methylchlorosilane			CH5ClSi	80.589	993-00-0
Hydrogen bromide	Bromane	HBr	BrH	80.912	10035-10-6
2-Methylfuran	Methylfuran	Sylvan	C5H6O	82.102	534-22-5
Cyclohexene			C6H10	82.144	110-83-8
3-Methylcyclopentene			C6H10	82.144	1120-62-3
1-Hexyne			C6H10	82.144	693-02-7
1-Methylcyclopentene			C6H10	82.144	693-89-0
2-Hexyne			C6H10	82.144	764-35-2
3-Hexyne			C6H10	82.144	928-49-4
Krypton			Kr	83.798	7439-90-9
1,1,1-Trifluoroethane	R-143a	Freon 143a	C2H3F3	84.041	420-46-2
1,1,2-Trifluoroethane	R-143		C2H3F3	84.041	430-66-0
Cyclopentanone			C5H8O	84.118	120-92-3
Thiophene	Thiofuran		C4H4S	84.14	110-02-1
Cyclohexane			C6H12	84.15948	110-82-7
1-Hexene	Hex-1-ene	Hexene	C6H12	84.159	592-41-6
Methylcyclopentane			C6H12	84.159	96-37-7
4-Methyl-1-pentene	4-Methylpent-1-ene		C6H12	84.15948	691-37-2
Dichloromethane	Methane dichloride	Methylene chloride	CH2Cl2	84.933	75-09-2
Vinyl acetate			C4H6O2	86.089	108-05-4
Methacrylic acid			C4H6O2	86.089	79-41-4
Methyl acrylate			C4H6O2	86.089	96-33-3
2-Pentanone	Pentan-2-one	Methyl propyl ketone	C5H10O	86.132	107-87-9

Preferred Name	Alternate Name 1	Alternate Name 2	Formula	Weight	CAS#
Pentanal			C5H10O	86.132	110-62-3
3-Methyl-2-butanone	3-Methyl butanone	Methyl isopropyl ketone	C5H10O	86.132	563-80-4
3-Pentanone	Diethyl ketone	Metacetone	C5H10O	86.132	96-22-0
2-Methylpentane	1,1-Dimethylbutane	Isohexane	C6H14	86.17536	107-83-5
Hexane	n-Hexane		C6H14	86.17536	110-54-3
2,3-Dimethylbutane	Diisopropyl	Biisopropyl	C6H14	86.175	79-29-8
2,2-Dimethylbutane	Neohexane		C6H14	86.17536	75-83-2
3-Methylpentane			C6H14	86.177	96-14-0
Chloro(difluoro)methane	R-22	Chlorodifluoromethane	CHClF2	86.468	75-45-6
Tetrafluoromethane	R-14	carbon tetrafluoride	CF4	88.01	75-73-0
Butyric acid			C4H8O2	88.105	107-92-6
Propyl formate	Propyl methanoate	n-Propyl methanoate	C4H8O2	88.105	110-74-7
1,4-Dioxane			C4H8O2	88.105	123-91-1
Ethyl acetate	Acetic ester	Ethyl ethanoate	C4H8O2	88.105	141-78-6
Methyl propionate			C4H8O2	88.105	554-12-1
Isobutyric acid			C4H8O2	88.105	79-31-2
1,3-Dioxane			C4H8O2	88.106	505-22-6
3-Methyl-1-butanol			C5H12O	88.148	123-51-3
Methyl tert-butyl ether	MTBE	tert-Butyl methyl ether	C5H12O	88.148	1634-04-4
2-Pentanol			C5H12O	88.148	6032-29-7
Methylisobutyl ether			C5H12O	88.148	625-44-5
Ethylisopropyl ether			C5H12O	88.148	625-54-7
Methylbutyl ether			C5H12O	88.148	628-28-4
Ethylpropyl ether			C5H12O	88.148	628-32-0
1-Pentanol	n-Amyl alcohol	Pentanol	C5H12O	88.148	71-41-0
2-Methyl-2-butanol	tert-Amyl Alcohol	2-Methylbutan-2-ol	C5H12O	88.15	75-85-4
Tetrahydrothiophene			C4H8S	88.171	110-01-0
Oxalic acid			C2H2O4	90.035	144-62-7
1,3-Butanediol			C4H10O2	90.121	107-88-0
1,1-Dimethoxyethane			C4H10O2	90.121	534-15-6
1,2-Butanediol			C4H10O2	90.121	584-03-2
Butyl mercaptan			C4H10S	90.187	109-79-5
Methylisopropyl sulfide			C4H10S	90.187	1551-21-9
Diethyl sulfide	ethyl sulfide	1,1-Thiobisethane	C4H10S	90.187	352-93-2
Methylpropyl sulfide			C4H10S	90.187	3877-15-4
sec-Butyl mercaptan			C4H10S	90.187	513-53-1
Methylbenzene	Toluene		C7H8	92.13842	108-88-3
2-Chlorobutane	1-Methylpropyl chloride	sec-Butyl chloride	C4H9Cl	92.568	78-86-4
4-Methylpyridine	4-Methylazine	4-Picoline	C6H7N	93.128	108-89-4
3-Methylpyridine	3-Mepy	3-Picoline	C6H7N	93.128	108-99-6
2-Methylpyridine	2-Picoline		C6H7N	93.128	109-06-8
Aniline	1-Aminobenzene	Benzenamine	C6H7N	93.128	62-53-3
Phenol	Benzenol	Hydroxybenzene	C6H6O	94.111	108-95-2
Dimethyl disulfide			C2H6S2	94.199	624-92-0
Bromomethane			CH3Br	94.939	74-83-9
Dimethylzinc	Zinc dimethanide	DMZn	C2H6Zn	95.478	544-97-8
Fluorobenzene			C6H5F	96.102	462-06-6
1-Heptyne			C7H12	96.17	628-71-7
Cyclohexanone			C6H10O	98.143	108-94-1
Methylcyclohexane			C7H14	98.186	108-87-2

Preferred Name	Alternate Name 1	Alternate Name 2	Formula	Weight	CAS#
Ethylcyclopentane			C7H14	98.186	1640-89-7
1-Heptene	Heptylene	Hept-1-ene	C7H14	98.186	592-76-7
(1R,3R)-1,3-Dimethylcyclopentane	1,trans-3-Dimethylcyclopentane	trans-1,3-Dimethylcyclopentane	C7H14	98.188	1759-58-6
(1R,3S)-1,3-Dimethylcyclopentane	cis-1,3-Dimethylcyclopentane		C7H14	98.188	2532-58-3
1,2-Dichloroethane	1,2-DCE	1,2-Ethylene dichloride	C2H4Cl2	98.959	107-06-2
1,1-Dichloroethane	1,1-DCE		C2H4Cl2	98.959	75-34-3
Tetrafluoroethene	1,1,2,2-Tetrafluoroethylene	Perfluoroethylene	C2F4	100.016	116-14-3
Methyl methacrylate			C5H8O2	100.116	80-62-6
Methylisobutyl ketone			C6H12O	100.159	108-10-1
Cyclohexanol	Cyclohexyl Alcohol	1-Cyclohexanol	C6H12O	100.159	108-93-0
Ethylisopropyl ketone			C6H12O	100.159	565-69-5
3-Hexanone	Hexan-3-one		C6H12O	100.159	589-38-8
2-Hexanone	Butyl methyl ketone	Hexan-2-one	C6H12O	100.159	591-78-6
Hexanal			C6H12O	100.159	66-25-1
2,4-Dimethylpentane	Diisopropylmethane		C7H16	100.202	108-08-7
Heptane	n-Heptane		C7H16	100.202	142-82-5
2,2,3-Trimethylbutane	Triptane	Pentamethylethane	C7H16	100.202	464-06-2
3,3-Dimethylpentane			C7H16	100.202	562-49-2
2,3-Dimethylpentane	Ethylisopropylmethyl methane		C7H16	100.202	565-59-3
3-Methylhexane	2-Ethylpentane		C7H16	100.202	589-34-4
2,2-Dimethylpentane			C7H16	100.202	590-35-2
2-Methylhexane	Isoheptane		C7H16	100.202	591-76-4
3-Ethylpentane			C7H16	100.202	617-78-7
1-Chloro-1,1-difluoroethane	R-142b	1,1-Difluoro-1-chloroethane	C2H3ClF2	100.495	75-68-3
Di-isopropyl amine			C6H15N	101.19	108-18-9
N,N-Diethylethanamine	TEA	Triethylamine	C6H15N	101.19	121-44-8
Dipropyl amine			C6H15N	101.19	142-84-7
1,1,2,2-Tetrafluoroethane	R-134	a,w-Dihydroperfluoroethane	C2H2F4	102.032	359-35-3
1,1,1,2-Tetrafluoroethane	R-134a	Tetrafluoroethane	C2H2F4	102.032	811-97-2
Acetic anhydride			C4H6O3	102.089	108-24-7
Ethyl propionate			C5H10O2	102.132	105-37-3
Pentanoic acid			C5H10O2	102.132	109-52-4
Propyl acetate	Propyl ethanoate	n-Propyl ethanoate	C5H10O2	102.132	109-60-4
2-Methylbutanoic acid			C5H10O2	102.132	116-53-0
Methyl butyrate			C5H10O2	102.132	623-42-7
Di-isopropyl ether			C6H14O	102.175	108-20-3
1-Hexanol	Caproic alcohol	Hexyl alcohol	C6H14O	102.175	111-27-3
2-Hexanol			C6H14O	102.175	626-93-7
Methyl pentyl ether			C6H14O	102.175	628-80-8
Dichloro(fluoro)methane	R-21	Dichlorofluoromethane	CHCl2F	102.92	75-43-4
Benzonitrile			C7H5N	103.121	100-47-0
Malonic acid			C3H4O4	104.061	141-82-2
Silicon tetrafluoride		SiF4	F4Si	104.079	7783-61-1
1,2-Dimethoxypropane			C5H12O2	104.148	7778-85-0
Styrene			C8H8	104.149	100-42-5
Pentyl mercaptan			C5H12S	104.214	110-66-7
2-Pentyl mercaptan			C5H12S	104.214	2084-19-7

Preferred Name	Alternate Name 1	Alternate Name 2	Formula	Weight	CAS#
Methylbutyl sulfide			C5H12S	104.214	628-29-5
Chloro(trifluoro)methane	R-13	Trifluorochloromethane	CClF3	104.459	75-72-9
Diethanol amine			C4H11NO2	105.136	111-42-2
Ethylbenzene			C8H10	106.165	100-41-4
p-Xylene	1,4-Xylene	1,4-Dimethylbenzene	C8H10	106.165	106-42-3
m-Xylene	1,3-Xylene	1,3-Dimethylbenzene	C8H10	106.165	108-38-3
o-Xylene	ortho-Xylene	1,2-Dimethylbenzene	C8H10	106.165	95-47-6
2,4-Dimethylpyridine	2,4-Lutidine		C7H9N	107.155	108-47-4
2,6-Dimethylpyridine	2,6-Lutidine		C7H9N	107.155	108-48-5
3,4-Dimethylpyridine	3,4-Lutidine		C7H9N	107.155	583-58-4
2,3-Dimethylpyridine	2,3-Lutidine		C7H9N	107.155	583-61-9
2,5-Dimethylpyridine	2,5-Lutidine	5-methyl-2-methylpyridine	C7H9N	107.155	589-93-5
3,5-Dimethylpyridine	3,5-Lutidine		C7H9N	107.155	591-22-0
Sulfur tetrafluoride	Tetrafluoro-λ4-sulfane	SF4	F4S	108.06	7783-60-0
Quinone			C6H4O2	108.095	106-51-4
Benzyl alcohol			C7H8O	108.138	100-51-6
Anisole			C7H8O	108.138	100-66-3
p-Cresol	4-Methylphenol	4-Hydroxytoluene	C7H8O	108.138	106-44-5
m-Cresol	3-Methylphenol	1-Hydroxy-3-methylbenzene	C7H8O	108.138	108-39-4
o-Cresol	2-Methylphenol	2-Hydroxytoluene	C7H8O	108.138	95-48-7
Bromoethane			C2H5Br	108.965	74-96-4
Benzenethiol			C6H6S	110.177	108-98-5
1-Octyne			C8H14	110.197	629-05-0
cis-1,2-Dimethylcyclohexane			C8H16	112.213	2207-01-4
1-Octene	Octene		C8H16	112.213	111-66-0
Ethylcyclohexane			C8H16	112.213	1678-91-7
1,1-Dimethylcyclohexane			C8H16	112.213	590-66-9
trans-1,2-Dimethylcyclohexane			C8H16	112.213	6876-23-9
Cyclooctane			C8H16	112.215	292-64-8
Chlorobenzene	Phenyl chloride	Benzyl chloride	C6H5Cl	112.557	108-90-7
1,2-Dichloropropane	Propylene dichloride		C3H6Cl2	112.986	78-87-5
1,1-Dichloropropane			C3H6Cl2	112.986	78-99-9
3-Heptanone			C7H14O	114.185	106-35-4
2-Heptanone			C7H14O	114.185	110-43-0
Heptanal			C7H14O	114.185	111-71-7
Di-isopropyl ketone			C7H14O	114.185	565-80-0
1-Methylcyclohexanol			C7H14O	114.185	590-67-0
trans-2-Methylcyclohexanol			C7H14O	114.185	7443-52-9
cis-2-Methylcyclohexanol			C7H14O	114.185	7443-70-1
Octane	n-Octane		C8H18	114.229	111-65-9
2,2,4-Trimethylpentane	Isooctane (trimethylpentane)		C8H18	114.229	540-84-1
2,3,3-Trimethylpentane			C8H18	114.229	560-21-4
3,3-Dimethylhexane			C8H18	114.229	563-16-6
2,2,3-Trimethylpentane			C8H18	114.229	564-02-3
3,4-Dimethylhexane			C8H18	114.229	583-48-2
2,3-Dimethylhexane			C8H18	114.229	584-94-1
2,4-Dimethylhexane			C8H18	114.229	589-43-5

Preferred Name	Alternate Name 1	Alternate Name 2	Formula	Weight	CAS#
4-Methylheptane			C8H18	114.229	589-53-7
2,2-Dimethylhexane			C8H18	114.229	590-73-8
2,5-Dimethylhexane	Diisobutane		C8H18	114.229	592-13-2
2-Methylheptane	i-Octane	Isooctane (methylheptane)	C8H18	114.229	592-27-8
2,2,3,3-Tetramethylbutane	Hexamethylethane		C8H18	114.229	594-82-1
3-Ethyl-2-methylpentane	2-Methyl-3-ethylpentane		C8H18	114.229	609-26-7
3-Ethylhexane			C8H18	114.229	619-99-8
Trimethylgallium	TMGa	Me3Ga	C3H9Ga	114.827	1445-79-0
Methyldichlorosilane			CH4Cl2Si	115.034	75-54-7
Ethyl butyrate			C6H12O2	116.158	105-54-4
Butyl acetate			C6H12O2	116.158	123-86-4
Hexanoic acid			C6H12O2	116.158	142-62-1
2-Ethyl butanoic acid			C6H12O2	116.158	88-09-5
1-Heptanol	1-Hydroxyheptane	Heptan-1-ol	C7H16O	116.201	111-70-6
2-Heptanol			C7H16O	116.201	543-49-7
Cyclohexyl mercaptan			C6H12S	116.224	1569-69-3
1,1-Dichloro-1-fluoroethane	R-141b	Dichlorofluoroethane	C2H3Cl2F	116.9496	1717-00-6
Succinic acid			C4H6O4	118.088	110-15-6
Ethyl (2S)-2-hydroxypropanoate	Ethyl lactate		C5H10O3	118.133	687-47-8
alpha-Methyl styrene			C9H10	118.176	98-83-9
Hexyl mercaptan			C6H14S	118.24	111-31-9
Phenyl isocyanate			C7H5NO	119.121	103-71-9
Chloroform	R-20	Trichloromethane	CHCl3	119.378	67-66-3
1,1,1,2,2-Pentafluoroethane	R-125	Pentafluoroethane	C2HF5	120.0214	354-33-6
Propylbenzene	n-Propylbenzene		C9H12	120.192	103-65-1
1,2,3-Trimethylbenzene	Trimethylbenzene		C9H12	120.192	526-73-8
1,2,4-Trimethylbenzene	pseudocumene	Pseudocumene	C9H12	120.192	95-63-6
1-methylethyl benzene	2-Phenylpropane	Cumene	C9H12	120.192	98-82-8
Mesitylene	Sym-Trimethylbenzene	1,3,5-Trimethylbenzene	C9H12	120.194	108-67-8
1-Ethyl-4-methylbenzene	1,4-Methylethylbenzene	4-Ethyltoluene	C9H12	120.194	622-96-8
Dichloro(difluoro)methane	R-12	dichlorodifluoromethane	CCl2F2	120.913	75-71-8
Benzamide			C7H7NO	121.137	55-21-0
Benzoic acid			C7H6O2	122.121	65-85-0
2,4-Dimethylphenol		2,4-Xylenol	C8H10O	122.167	105-67-9
3,5-Dimethylphenol	1,3,5-Xylenol	3,5-Xylenol	C8H10O	122.167	108-68-9
4-Ethylphenol	p-Ethylphenol	4-Hydroxyethylbenzene	C8H10O	122.167	123-07-9
2,3-Dimethylphenol	1-Hydroxy-2,3-dimethylbenzene	Xylenol	C8H10O	122.167	526-75-0
2,6-Dimethylphenol	1-Hydroxy-2,6-dimethylbenzene	2,6-Xylenol	C8H10O	122.167	576-26-1
3-Ethylphenol	3-Ethylbenzolol	1-Hydroxy-3-ethylbenzene	C8H10O	122.167	620-17-7
2-Ethylphenol	2-Ethylphenyl alcohol	1-Hydroxy-2-ethylbenzene	C8H10O	122.167	90-00-6
3,4-Dimethylphenol	1,2-Dimethyl-4-hydroxybenzene	3,4-Xylenol	C8H10O	122.167	95-65-8
2,5-Dimethylphenol	2,5-Dimethylbenzolol	1,2,5-Xylenol	C8H10O	122.167	95-87-4
Propenylcyclohexene			C9H14	122.207	13511-13-2
Benzyl mercaptan			C7H8S	124.203	100-53-8
1-Nonyne			C9H16	124.223	3452-09-3
1-Nonene	Non-1-ene		C9H18	126.239	124-11-8
Hydrogen iodide	Iodane	Hydroiodic acid	HI	127.912	10034-85-2

Preferred Name	Alternate Name 1	Alternate Name 2	Formula	Weight	CAS#
Naphthalene			C10H8	128.171	91-20-3
3-Octanone			C8H16O	128.212	106-68-3
2-Octanone			C8H16O	128.212	111-13-7
Octanal			C8H16O	128.212	124-13-0
Nonane	n-Nonane		C9H20	128.2551	111-84-2
2,2,4,4-Tetramethylpentane	Di-tert-butylmethane		C9H20	128.2551	1070-87-7
2,2,3,4-Tetramethylpentane			C9H20	128.2551	1186-53-4
2,3,3,4-Tetramethylpentane			C9H20	128.2551	16747-38-9
2-Methyloctane	Isononane		C9H20	128.2551	3221-61-2
Heptanoic acid			C7H14O2	130.185	111-14-8
1-Octanol	Capyrl alcohol	1-Octyl alcohol	C8H18O	130.228	111-87-5
2-Octanol			C8H18O	130.228	123-96-6
Dibutyl ether			C8H18O	130.228	142-96-1
Ethylhexyl ether			C8H18O	130.228	5756-43-4
Bromo(difluoro)methane	bromodifluoromethane	Difluorobromomethane	CHBrF2	130.92	1511-62-2
Xenon			Xe	131.293	7440-63-3
1,2,3,4-Tetrahydronaphthalene			C10H12	132.202	119-64-2
Heptyl mercaptan			C7H16S	132.267	1639-09-4
1,1,2-Trichloroethane			C2H3Cl3	133.404	79-00-5
1,1,2,2,3-pentafluoropropane	R-245ca		C3H3F5	134.0479	679-86-7
1,1,1,3,3-pentafluoropropane	R-245fa		C3H3F5	134.0479	460-73-1
Butylbenzene	n-Butylbenzene	Butyl benzene	C10H14	134.218	104-51-8
1,4-Diethylbenzene	para-Diethylbenzene	p-Diethylbenzene	C10H14	134.221	105-05-5
1,2,4,5-Tetramethylbenzene	Durene		C10H14	134.221	95-93-2
Trichlorosilane	SiHCl3		HCl3Si	135.452	10025-78-2
Methyl benzoate			C8H8O2	136.148	93-58-3
Benzyl ethyl ether			C9H12O	136.191	539-30-0
2-Chloro-1,1,1,2-tetrafluoroethane	R-124	1,1,1,2-tetrafluoro-2-chloroethane	C2HClF4	136.475	2837-89-0
1-Chloro-1,1,2,2-tetrafluoroethane	R-124a	1,1,2,2-Tetrafluorochloroethane	C2HClF4	136.476	354-25-6
Trichloro(fluoro)methane	R-11	Trichlorofluoromethane	CCl3F	137.368	75-69-4
Hexafluoroethane	R-116	Perfluoroethane	C2F6	138.0118	76-16-4
1-Decyne			C10H18	138.25	764-93-2
cis-Decahydronaphthalene	(4as,8as)-Decahydronaphthalene	cis-Decalin	C10H18	138.253	493-01-6
trans-Decahydronaphthalene	(4ar,8ar)-Decahydronaphthalene	trans-Decalin	C10H18	138.253	493-02-7
1-Decene	Dec-1-ene	Decylene	C10H20	140.266	872-05-9
2,2,5-Trimethylheptane			C10H22	142	20291-95-6
1-Methylnaphthalene	Methyl-1-naphthalene		C11H10	142.2	90-12-0
Nonanal			C9H18O	142.239	124-19-6
2,2,3,3-Tetramethylhexane			C10H22	142.2817	13475-81-5
3,3,5-Trimethylheptane			C10H22	142.2817	7154-80-5
Decane	n-decane		C10H22	142.2817	124-18-5
Dihydrogen hexafluorosilicate	Hexafluorosilicic acid	SiF6	H2F6Si	144.09	16961-83-4
Octanoic acid			C8H16O2	144.211	124-07-2

Preferred Name	Alternate Name 1	Alternate Name 2	Formula	Weight	CAS#
2-Ethyl hexanoic acid			C8H16O2	144.211	149-57-5
1-Nonanol	Nonylol	Nonyl alcohol	C9H20O	144.255	143-08-8
2-Nonanol			C9H20O	144.255	628-99-9
Sulfur hexafluoride	Hexafluoro-λ6-sulfane	SF6	F6S	146.0554	2551-62-4
Octyl mercaptan			C8H18S	146.294	111-88-6
p-Dichlorobenzene			C6H4Cl2	147.002	106-46-7
m-Dichlorobenzene			C6H4Cl2	147.002	541-73-1
o-Dichlorobenzene			C6H4Cl2	147.002	95-50-1
1,1,1,3,3-pentafluorobutane	R-365mfc		C4H5F5	148.0745	406-58-6
Phthalic anhydride			C8H4O3	148.116	85-44-9
Bromo(trifluoro)methane	R-13B1	CFC 13B1	CBrF3	148.91	75-63-8
Ethyl benzoate			C9H10O2	150.175	93-89-0
1,1,1,2,3,3-hexafluoropropane	R-236ea		C3H2F6	152.0384	431-63-0
1,1,1,3,3,3-hexafluoropropane	R-236fa		C3H2F6	152.0384	690-39-1
2,2-Dichloro-1,1,1-trifluoroethane	R-123	Dichlorotrifluoromethyl methane	C2HCl2F3	152.931	306-83-2
Phosphoric trichloride	Phosphoryl chloride	Phosphorus oxychloride	Cl3OP	153.332	10025-87-3
Tetrachloromethane	R-10	Carbon tetrachloride	CCl4	153.823	56-23-5
Biphenyl	1,1'-Biphenyl	Phenylbenzene	C12H10	154.208	92-52-4
1-Chloro-1,1,2,2,2-pentafluoroethane	R-115	1-Chloropentafluoroethane	C2ClF5	154.4664	76-15-3
Di-1,3-cyclopentadien-1-yl magnesium	Bis(cyclopentadienyl) magnesium	Cp2Mg	C10H10Mg	154.491	1284-72-6
Decanal			C10H20O	156.265	112-31-2
Undecane			C11H24	156.308	1120-21-4
Triethylgallium	TeGa		C6H15Ga	156.906	1115-99-7
Bromobenzene			C6H5Br	157.008	108-86-1
Nonanoic acid			C9H18O2	158.238	112-05-0
2-Methyloctanoic acid			C9H18O2	158.238	3004-93-1
1-Decanol	1-Hydroxydecane	Decan-1-ol	C10H22O	158.281	112-30-1
Bromine			Br2	159.808	7726-95-6
Trimethylindium	TMI		C3H9In	159.922	3385-78-2
Nonyl mercaptan			C9H20S	160.32	1455-21-6
Vinyl trichlorosilane			C2H3Cl3Si	161.49	75-94-5
1,3,5-Triethylbenzene			C12H18	162.276	102-25-0
Ethyltrichlorosilane			C2H5Cl3Si	163.506	115-21-9
Bromo(chloro)difluoro methane	R-12B1	Chlorobromodifluoro methane	CBrClF2	165.365	353-59-3
Terephthalic acid			C8H6O4	166.131	100-21-0
1,2,3,4,5-Pentafluorobenzene	Pentafluorobenzene		C6HF5	168.066	363-72-4
Tetrachlorosilane	Silicon tetrachloride	SiCl4	Cl4Si	169.896	10026-04-7
1,1,1,2,3,3,3-heptafluoropropane	R-227ea		C3HF7	170.0289	431-89-0
Diphenyl ether			C12H10O	170.207	101-84-8
Dodecane	n-Dodecane		C12H26	170.3348	112-40-3
1,1-Dichloro-1,2,2,2-tetrafluoroethane	R-114a	Dichlorotetrafluroethane	C2Cl2F4	170.921	374-07-2
1,2-Dichloro-1,1,2,2-tetrafluoroethane	R-114	Cryofluorane	C2Cl2F4	170.921	76-14-2

Preferred Name	Alternate Name 1	Alternate Name 2	Formula	Weight	CAS#
Decanoic acid			C10H20O2	172.265	334-48-5
1-Undecanol			C11H24O	172.308	112-42-5
Dibromomethane			CH2Br2	173.835	74-95-3
Decyl mercaptan			C10H22S	174.347	143-10-2
Phenanthrene			C14H10	178.229	85-01-8
Anthracene			C14H10	178.233	120-12-7
Benzophenone			C13H10O	182.218	119-61-9
Tridecane		n-Tridecane	C13H28	184.361	629-50-5
Hexafluorobenzene	Perfluorobenzene		C6F6	186.056	392-56-3
1-Dodecanol	1-Hydroxydodecane	Dodecan-1-ol	C12H26O	186.338	112-53-8
1,1,2-Trichloro-1,2,2-trifluoroethane	R-113	Daiflon 113	C2Cl3F3	187.375	76-13-1
1,2-Dibromoethane	Ethylene dibromide		C2H4Br2	187.861	106-93-4
1,1-Dibromoethane			C2H4Br2	187.861	557-91-5
Octafluoropropane	R-218	2,2-Dihydroperfluoropropane	C3F8	188.0193	76-19-7
Dimethyl terephthalate			C10H10O4	194.184	120-61-6
Dimethyl phthalate			C10H10O4	194.184	131-11-3
trifluoroiodomethane	trifluoroiodomethane		CF3I	195.9104	2314-97-8
Tetradecane	n-Tetradecane		C14H30	198.388	629-59-4
Octafluorocyclobutane			C4F8	200.04	115-25-3
1-Chloro-2,3,4,5,6-pentafluorobenzene	Perfluorochlorobenzene	Chloropentafluorobenzene	C6ClF5	202.511	344-07-0
Tetraethyl orthosilicate	TEOS	Silicic acid	C8H20O4Si	208.327	78-10-4
Dibromo(difluoro)methane	R-12B2	Dibromodifluoromethane	CBr2F2	209.816	75-61-6
Pentadecane	n-Pentadecane		C15H32	212.415	629-62-9
1,3,5-Trinitrobenzene			C6H3N3O6	213.105	99-35-4
Tetrachlorogermane	Germanium chloride	GeCl4	Cl4Ge	214.421	10038-98-9
Radon			Rn	222.018	10043-92-2
Tetrakis(dimethylamido) titanium(IV)	TDMAT	[(CH3)2N]4Ti	C8H24N4Ti	224.17	3275-24-9
Hexadecane	n-Hexadecane	Cetane	C16H34	226.441	544-76-3
2,4,6-Trinitrotoluene			C7H5N3O6	227.131	118-96-7
o-Terphenyl			C18H14	230.304	84-15-1
perfluorobutane	decafluorobutane		C4F10	238.03	355-25-9
Heptadecane			C17H36	240.468	629-78-7
Octadecane	n-Octadecane		C18H38	254.494	593-45-3
Nonadecane			C19H40	268.521	629-92-5
Eicosane			C20H42	282.547	112-95-8
Dodecafluoropentane	Perfluoro-n-pentane	Perflenapent	C5F12	288.03	678-26-2
Tungsten hexafluoride	Tungsten(VI) fluoride	WF6	F6W	297.83	7783-82-6
Tetrabromomethane	Carbon tetrabromide		CBr4	331.627	558-13-4
Tetrakis(diethylamido) titanium(IV)	TDEAT	[(C2H5)2N]4Ti	C16H40N4Ti	336.383	4419-47-0
Tetradecafluorohexane	n-Tetradecafluorohexane	Perfluorohexane	C6F14	338.044	355-42-0
Tetrabromosilane	Silicon tetrabromide		Br4Si	347.702	7789-66-4
Hexadecafluoroheptane	Perfluoroheptane		C7F16	388.052	335-57-9
Octadecafluorooctane	Perfluorooctane		C8F18	438.059	307-34-6
Icosafluorononane	Perfluorononane	Eicosafluorononane	C9F20	488.067	375-96-2
Docosafluorodecane	Perfluorodecane		C10F22	538.075	307-45-9

Gas Table Properties

The BGA244 binary gas analyzer determines gas purity and mixture compositions by measuring the temperature and the speed of sound in the gas. The speed of sound in an ideal gas is given by the follow equation.

$$W_o = \sqrt{\frac{\gamma_0 R T}{M}} \qquad \text{Eq. 1}$$

Where W_o is the speed of sound in the ideal gas (low pressure) limit, γ_0 the ratio of heat capacities, M the molar mass, T the absolute temperature, and R the ideal gas constant. For argon, $\gamma_0 = C_p/C_v = C_p/(C_p - R) = 5/3$ and $M = 0.039948\ kg/mol$, and so the ideal speed of sound at 20°C (293.15 K) is about 318.89 m/s.

For the BGA244 to determine the purity of an *ideal* gas it needs to know the isobaric heat capacity (C_p) and M. The measurement of *real* gases will be improved if the other thermodynamic and transport properties, and the gas pressure, are also known.

The Gas Table contains information on about 500 gases listed by common names, formulas, and registration numbers. In addition to the molar mass, the Gas Table provides parameters to estimate each of the following (all of which can modify the speed of sound in the gas): The temperature dependence of the heat capacity, the second and third virial coefficients, the viscosity and thermal conductivity as functions of temperature, the translational/vibrational relaxation of the heat capacity, and the saturation vapor pressure.

In addition, the Gas Table provides information on the critical parameters (P_c, V_c, T_c, Z_c), the Pitzer acentric factor, the electric dipole moment, and chemical family allowing the computation of cross virial coefficients by the BGA244 firmware.

Finally, to allow for gas specific corrections caused by uncertainties in all the other parameters, there are three offset parameters to repair a fixed offset or offsets which change linearly with pressure or temperature.

As shown in *Table 25* there are 46 data fields (columns) associated with each gas. The table shows the column number, names, units, value for nitrogen, and a brief description for each of the column entries. A more complete description of each column follows.

TABLE 24: LIST OF 46 GAS TABLE PROPERTIES PROVIDED FOR EACH GAS (VALUES FOR NITROGEN ARE SHOWN IN TABLE)

Column	Name	Units	N2 Value	Description
1	CAS#	Alpha-numeric	7727-37-9	Chemical Abstract Service number
2	Preferred name	Alpha-numeric	Nitrogen	Preferred name. Often the systematic name if not arcane.
3	Alt 1 name	Alpha-numeric		Alternate name or ASKRAE designation. Example: R-134A
4	Alt 2 name	Alpha-numeric		Alternate name or non-Hill formula. Example: SF6 rather than F6S
5	Formula	Hill form	N2	Chemical formula, carbon(s) first, hydrogen(s) next, alpha thereafter
6	Molar mass	g/mol	28.01348	Molecular weight in grams per mole
7	a0(Cp)	dimensionless	3.4379	Scaled coefficient of polynomial for isobaric heat capacity in units of R
8	a1(Cp)×1E+03	1/K	0.7884	Scaled coefficient of polynomial for isobaric heat capacity in units of R
9	a2(Cp)×1E+05	1/K^2	-0.3505	Scaled coefficient of polynomial for isobaric heat capacity in units of R
10	a3(Cp)×1e+08	1/K^3	0.6090	Scaled coefficient of polynomial for isobaric heat capacity in units of R
11	a4(Cp)×1e+11	1/K^4	-0.2508	Scaled coefficient of polynomial for isobaric heat capacity in units of R
12	Cp(Tnorm)/R	dimensionless	3.5026997	Isobaric heat capacity (in units of R) calculated from polynomial at T=T(norm)
13	Wo(Tnorm, P=0)	m/s	348.963	Ideal gas speed of sound at T_norm. Wo=sqrt(γRT/M)
14	Pc	bar	33.958	Critical pressure (bar)
15	Vc	cc/mol	89.414	Critical volume (cc/mol)
16	Tc	K	126.192	Critical temperature (K)
17	Zc	dimensionless	0.289387	Critical compressibility
18	Acentric factor	dimensionless	0.0	Pitzer acentric factor
19	Dipole moment	D (debye)	0.00	Electric dipole moment
20	Family	Integer	1	Integer (1-6) to describe chemical "family" per table, below. (For CSP methods)
21	a_Tsono	dimensionless	0.00	Tsonopoulos correlation a-parameter for 2nd virial (see PG&L Pg 4.15)
22	b_Tsono	dimensionless	0.00	Tsonopoulos correlation b-parameter for 2nd virial (see PG&L Pg 4.15)
23	av	cc/mol	144.14	Zuckerwar parameter for exponential form of 2nd virial. (See Eq 4.30, pg 94)
24	bv	cc/mol	101.08544	Zuckerwar parameter for exponential form of 2nd virial. (See Eq 4.30, pg 94)
25	cv	K	115.778	Zuckerwar parameter for exponential form of 2nd virial. (See Eq 4.30, pg 94)
26	dv	[cc/mol]^2	16689.36	Zuckerwar parameter for exponential form of 3rd virial. (See Eq 4.35, pg 98)
27	ev	[cc/mol]^2	49.618	Zuckerwar parameter for exponential form of 3rd virial. (See Eq 4.35, pg 98)
28	fv	K	552.72650	Zuckerwar parameter for exponential form of 3rd virial. (See Eq 4.35, pg 98)
29	gv	1/K	0.015	Zuckerwar parameter for exponential form of 3rd virial. (See Eq 4.35, pg 98)
30	C_asymptote	[cc/mol]^2	1188.1	Zuckerwar parameter for exponential form of 3rd virial. (See Eq 4.35, pg 98)
31	a0(η)	µPa-s	1.66702397	Polynomial coefficient for viscosity, η(T)
32	a1(η)×100	µPa-s/K	6.22979799	Polynomial coefficient for viscosity, η(T)
33	a2(η)×10,000	µPa-s/K^2	-0.28410365	Polynomial coefficient for viscosity, η(T)
34	a0(κ)	mW/m.K	1.904	Polynomial coefficient for thermal conductivity κ(T)
35	a1(κ)×100	mW/m.K^2	8.706	Polynomial coefficient for thermal conductivity κ(T)
36	a2(κ)×10,000	mW/m.K^3	-0.267	Polynomial coefficient for thermal conductivity κ(T)
37	Vib Temp	K	3352.00	Characteristic temperature for excitation of vibrational mode
38	a1_r	dimensionless	-3.65	Coefficient for relaxation-time x pressure product (us-atm)
39	a2_r	K^1/3	71.63	Coefficient for relaxation-time x pressure product (us-atm)
40	a3_r	K	0.00	Coefficient for relaxation-time x pressure product (us-atm)
41	A_vp	Result in Pa	0.00	Coefficient for the Antoine Equation for vapor pressure. (PG&L Eq 7-3.1, pg 7.4)
42	B_vp	Result in Pa	0.00000	Coefficient for the Antoine Equation for vapor pressure. (PG&L Eq 7-3.1, pg 7.4)
43	C_vp	Result in Pa	0.00000	Coefficient for the Antoine Equation for vapor pressure. (PG&L Eq 7-3.1, pg 7.4)
44	W_offset	ppm	0.00	Empirical offset for the computed speed of sound
45	W_Pslope	ppm/psi	0.00	Empirical pressure slope for the computed speed of sound
46	W_Tslope	ppm/T	0.00	Empirical temperature slope for the computed speed of sound

CAS Registry number (Column 1)

The CAS registry number is a unique identifier assigned by the Chemical Abstract Service (CAS) to every chemical substance described in reviewed scientific literature. The CAS numbers are used by chemical suppliers, governmental regulators, safety data sheets (MSDS), chemical and thermodynamic databases. Using the CAS number (instead of a chemical name) will assure that correct gas has been selected. The CAS Registry Number is a Registered Trademark of the American Chemical Society.

Preferred name (Column 2)

Except for a few arcane cases (for example, “carbon dioxide” is used instead of “methanedione” and “ozone” is used instead of “2-trioxiden-2-ium-1-ide”) the preferred name is usually the IUPAC name (International Union of Pure and Applied Chemistry).

First and second alternate names (Column 3 & 4)

Many compounds are commonly called by more than one name. For example, difluoromethane (CH_2F_2) is also called methylene fluoride and is an ASHRAE registered refrigerant designated as R-32. The alternate name columns accommodate these other names and industry designations.

Formula (Columns 5)

Formulas for compounds may be written in several ways. The BGA244 uses a simple, non-structural form called Hill notation. The rules are simple: For molecules containing carbon, the carbons are listed first, followed by the hydrogens, followed by everything else in alphabetical order of the element symbols. If the compound contains no carbons everything is listed in alphabetical order of the element symbols, including hydrogen. This system yields sensible results in most cases, for example, methane is CH4. There are a few exceptions however: SF6 is written F6S in Hill notation. In such cases the formula SF6 is included as one of the alternate names so that a user looking for SF6 will indeed find sulfur hexafluoride.

Source of data

Many references (listed at the end of this section) were used to compile (or calculate) the data used in the Gas Table. Data from those references was critically evaluated, primarily by comparison between the various references but also taking into consideration the sources used by those references.

Not all references had all of the data required for the Gas Table. Different references also used different correlation functions and applied those functions to different temperature ranges. As an example, consider the parameterization of the isobaric heat capacity vs. temperature. The BGA244 uses a 4^{th} order polynomial for this task. This polynomial is well behaved and offers more than enough flexibility to accurately follow the heat capacity over the BGA244’s operating temperature range. This is the same polynomial as used in one of the references, however, the accuracy of the coefficients presented in that reference where found to be less accurate than could be found by fitting a polynomial over the operating temperature range to data extracted from the correlation functions of other references, or to data extracted from NIST’s REFPROP.

The same methodology was applied to other gas parameters and parameters for correlation functions to estimate the second and third virial coefficients, the viscosity and thermal conductivity as functions of temperature, the translational/vibrational relaxation of the heat capacity, and the saturation vapor pressure. The distillation of all of these estimates and the parameters for new correlation functions are presented in the Gas Table.

Corresponding States Principle (CSP)

CSP methods allow the estimation of fluid properties which depend on intermolecular forces by correlation functions scaled with the critical constants of the fluid. For example, the departure from ideal gas compressibility can be described with a virial equation of state (EOS). The first two coefficients of that EOS, called the 2nd and 3rd virial coefficients, can be measured directly or estimated using CSP methods.

CSP methods were used to estimate the gases' 2nd and 3rd virial coefficients, thermal conductivity and viscosity. These results would be used in the Gas Table if experimental results (or correlation functions derived from those results) were not available.

Molar mass (Column 6)

The molar mass is in units of grams per mole. Note that these are not SI units, for which the molar mass is in kg/mole. An accurate molar mass is critically important as a 200 ppm error in the molar mass results in a 100 ppm error in the speed of sound. The molar mass is often rounded to two or three digits in published tables which is insufficient for the lighter gases.

Isobaric heat capacity, C_p/R (Columns 7-12)

The isobaric heat capacity in the ideal gas limit, in units of the ideal gas constant, is computed from the scaled coefficients to the 4th order polynomial given in Columns 7-11. (The coefficients are scaled to keep their magnitude on order 1.) C_p/R is computed from Eq. 2 (where T is the temperature in K):

$$\frac{C_p}{R} = a0 + \frac{a1 \cdot T}{1000} + \frac{a2 \cdot T^2}{100{,}000} + \frac{a3 \cdot T^3}{100{,}000{,}000} + \frac{a4 \cdot T^4}{100{,}000{,}000{,}000} \qquad \text{Eq. 2}$$

And the ratio of heat capacities, γ_0 , is computed from Eq. 3:

$$\gamma_0 = \frac{C_p}{C_v} = \frac{C_p}{C_p - R} = \frac{C_p/R}{C_p/R - 1} \qquad \text{Eq. 3}$$

Column 12 of the Gas Table holds the value of $C_p(T_{norm})/R$ where $T_{norm} = 293.15\ K$. This value serves as a computational check point, allowing the BGA244 firmware to validate the table contents and its method for computing heat capacity.

Speed of sound at normal temperature (Column 13)

The speed of sound at normal temperature (293.15 K), and in the zero pressure limit, is given in Column 13 in units of meters/second. This value can serve as a computational check of other table values and firmware algorithms, and is useful for sorting the Gas Table by the speed of sound. Such a sort provides prospective on the ability of the BGA244 to measure the composition of a gas mixture: It is difficult to measure the composition of a mixture of two gases which have nearly the same speed of sound.

Tsonopoulos correlation

The Tsonopoulos correlation is a CSP method which is used to estimate the 2nd virial. Absent experimental measurements, this method was used to estimate the 2nd and 3rd virial coefficients of pure gases in the Gas Table.

The method is also used by the BGA244 firmware to estimate the 2nd cross-virials of a gas mixture. This computation is done in firmware (instead of listed in the Gas Table) due to the large number (125,000) possible mixtures for 500 different gases.

To compute the 2nd cross-virial via the Tsonopoulos correlation the firmware will require the critical constants ($P_c, V_c, T_c, \text{and } Z_c$), acentric factor, dipole moment, and categorization into one of six chemical families. The details for those values are detailed below.

Critical constants (Columns 13-17)

The critical constants for each substance: $P_c, V_c, T_c, \text{and } Z_c$, are listed in Columns 13-17. The critical pressure is in units of bar. (1 bar = 100,000 Pa). The critical volume is in units of cc/mole. The critical temperature is in units of kelvin and the critical compressibility is dimensionless.

Acentric Factor (Column 18)

The Pitzer acentric factor is used to characterize the departure of thermodynamic properties of a substance from those predicted by two-parameter corresponding states principles (CSP). As CSP applies strictly only to spherical molecules, the acentric factor is considered to be a measure of the acentricity of the molecule. The acentric factor is dimensionless, and is determined from the departure of vapor pressures from those predicted for spherical molecules (such as noble gases.)

Dipole moment (Column 19)

The electric dipole moment of the substance in the gas phase is given in Column 19 in units of D (debye). Debye are not SI units, but provide a dipole value which is on order 1 for molecules. $1\ D \approx 3.33564 \times 10^{-30}\ C \cdot m = 0.208194\ e \cdot \text{Å}$.

Chemical Family (Column 19)

The Tsonopoulos correlation uses different correlation terms depending on the nature of the species, which are categorized into one of six chemical "families" as shown below.

Family	Description
1	Simple, Normal gases
2	Keytones, Aldehydes, Alkyl Nitriles, Ethers, Carboxylic Acid Esters
3	1-Alkanols except methanol
4	Methanol
5	Water

Tsonopoulos a,b parameters (Column 20-21)

These parameters, which are detailed in Table 4-5 on page 4.15 in PG&L are used in the Tsonopoulos correlation to compute the 2nd virial coefficients and 2nd cross-virial coefficients via a CSP method. (Note there is an error in the table in PG&L for the exponent for the a-parameter for Alkyl Halides, Mercaptans, Sulfides, and Disulfides: -2.188×10^{-4} should read -2.188×10^{-11} per original published papers.)

Second virial coefficient parameters (Column 23-25)

The second virial coefficient, $B(T)$, is parameterized as a function of temperature as shown in Eq. 4. (See Zuckerwar 4.30-4.32b):

$$B(T) = a_v - b_v e^{(c_v/T)} \qquad \text{Eq. 4}$$

The coefficients, a_v, b_v and c_v (with units of cc/mol, cc/mol and K) are found in columns 23-25 of the Gas Table. Several sources where used for these parameters including: Fitting the above equation to values for the 2nd virial computed over the operating temperature range from REFPROP, or by using coefficients directly from Zuckerwar or from Kaye & Laby, or (lastly) fitting the above equation to values for the 2nd virial computed from the Tsonopoulos correlation.

The 2nd virial and its first and second temperature derivatives alter the speed of sound in a manner which increases linearly with gas density. For many gases the virial correction for the speed of sound will be a small correction. For example, in methane at 1.6 atm and 300K, virial effects reduce the speed of sound by only 0.12%. However, even this small factor may be important in determining relative concentrations of species which are close in molecular weight.

Third virial coefficient parameters (Column 26-30)

The 3rd virial as a function of temperature is represented Eq. 5 (See Zuckerwar's Eq 4.35).

$$C(T) = \left[d_v - e_v \cdot \exp\left(\frac{f_v}{T}\right)\right] \cdot \exp(-g_v \cdot T) + C_{asymptote} \qquad \text{Eq. 5}$$

The parameters of this equation, $d_v, e_v, f_v, g_v \; and \; C_{asymptote}$ are given in columns 26-30 of the Gas Table. The units for these parameters are $cc/mol^2, cc/mol^2, K, K^{-1}$ and cc/mol^2.

Coefficients for the 3rd virial were sourced from Zuckerwar, computed from a CSP method by Orbey, or extracted from NIST's REFPROP program. All three methods provided reasonable agreement for common gases, but very disparate results for less common gases. There is a scarcity of reliable experimental results for the 3rd virial, and the method of Orbey does not address polar compounds, hence coefficients for the 3rd viral are missing for many substances.

The 3rd virial and its first and second temperature derivatives alter the speed of sound in a manner which increases quadratically with gas density. The impact is vanishingly small below a few atmospheres for most gases, but impacts the speed of sound by about 0.3% in SF_6 at ten atmospheres at 25C.

Finally, we suspect that literature reports of 2nd virial measurements have often conjoined 3rd virial effects into their fits. (We have seen cases where explicitly adding in the 3rd virial overcorrects.)

Viscosity (Columns 31-33)

The viscous boundary layer (typically a few 0.001") impacts the cavity resonance frequency by a fraction of a percent. The effect can be compensated for if we know the gas viscosity. The viscosity of a gas is approximated by the polynomial as shown in Eq. 6.

$$\eta = A_\eta + B_\eta \cdot T + C_\eta \cdot T^2 \qquad \text{Eq. 6}$$

Here, T is the absolute temperature in K. Coefficients for the polynomial, $A_\eta, B_\eta \; and \; C_\eta$, are tabulated for each gas and scaled so that the result has units of µPa-s.

Polynomial coefficients were determined by least squares fitting to viscosity data points over the operating temperature range. Data points were extracted from NIST's REFPROP, computed from correlation functions provided by Perry or PG&L, or computed from the CSP method of Lucas (see PG&L 9.9).

Thermal conductivity (Columns 34-36)

The thermal boundary layer (typically a few 0.001") impacts the cavity resonance frequency by a fraction of a percent. The effect can be compensated for if we know the thermal conductivity of the gas. The thermal conductivity of a gas is approximated by the polynomial in Eq. 7.

$$\eta = A_\kappa + B_\kappa \cdot T + C_\kappa \cdot T^2 \qquad \text{Eq. 7}$$

Here, T is the absolute temperature in K. Coefficients for the polynomial, $A_\kappa, B_\kappa \; and \; C_\kappa$, are tabulated for each gas and scaled so that the result has units of mW/m-K (1000x larger than SI value with units of W/m-K).

Polynomial coefficients were determined by least squares fitting to thermal conductivity data points over the operating temperature range. Data points were extracted from NIST's REFPROP, computed from correlation functions provided by Perry or PPL&G, or computed from the CSP method of Chung (1984, 1988) following PG&L Eq. 10-3.14

Heat capacity relaxation parameters (Columns 37-40)

There are a few gases for which vibrational energy levels (which contribute to the heat capacity) do not have time to equilibrate with the translational energy during the period of an acoustic cycle. The relaxation correction may be thought of as a correction to the heat capacity of the gas: If the relaxation time, τ_d , is longer than the acoustic cycle then vibrational degrees of freedom are partially frozen out, the heat capacity is lower, and so γ and the speed of sound will be higher. Without a correction for this effect, the computed speeds of sound (as is reported by NIST's REFPROP program, for example, which computes the speed of sound at zero frequency) are lower than the actual speed of sound.

We follow Zuckerwar's approach for the relaxation correction to the square of the speed of sound W^2 as shown in Eq. 8:

$$W^2 = W_\theta^2 \left[1 + \frac{\varepsilon}{1-\varepsilon} \cdot \frac{(\omega\tau_d)^2}{1+(\omega\tau_d)^2}\right] \qquad \text{Eq. 8}$$

Here W_θ^2 is the speed of sound (squared) corrected for the static heat capacity and virial effects (but not relaxation effects), ε is the relaxation strength, τ_d is the relaxation time and $\omega = 2\pi \cdot f_{101}$. The vibrational temperature (in K) in column 37 allows the firmware to compute ε and the coefficients in columns 38-40 allow the computation of τ_d. Computationally, we cast Zuckerwar's correction as a frequency dependence of the heat capacity.

Vapor pressure (Columns 41-43)

The saturation vapor pressure of the gas is computed to warn that the system may be close to condensation (which can impact the speed of sound or fill the chamber with liquid) and to limit the range of composition computational results.

The Antoine equation, Eq. 9, is used to model the saturation vapor pressure over the operating temperature range.

$$P_{vp}^{sat}(bar) = 10^{\left[A - \frac{B}{T+C}\right]} \qquad \text{Eq. 9}$$

Values for A, B and C are given in columns 41-43 of the Gas Table. These values were found by fitting the Antoine equation to vapor pressure data points over the operating temperature range. Vapor pressure data points were generated from multiple sources, including, NIST's REFPROP and correlation functions and parameters found in Perry, PG&L, PPL&G.

Vapor pressure data is omitted for fluids with critical temperatures below 265 K (as these fluids cannot be liquids at the BGA244 operating temperatures). In cases where no vapor pressure data is available, the BGA244 will not provide condensation warnings and will not limit composition results to below the saturation vapor pressure.

Speed of sound offsets (Columns 44-46)

The BGA244 computes the theoretical speed of sound using accurate molar masses, temperature corrected heat capacities, virial corrections, and translational-vibrational relaxation corrections. The speed of sound is measured using the thermo-viscous corrected resonance frequency and a cavity factor which has been corrected for perturbations and transducer resonances. Uncertainties in all of these corrections can lead to discrepancies between the measured and the computed speed of sound on order of +/- 100 ppm. An empirical speed of sound offset $W_{offset}(ppm)$, pressure correction $W_{P-slope}(ppm/psi)$ and temperature correction $W_{T-slope}(ppm/K)$ for each gas are used to repair these discrepancies. Values for those corrections are given in columns 44-46 of the Gas Table (and are initially set to zero).

References

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Appendix B: BGA244E

The BGA244E Enclosure Option allows the BGA244 to be mounted in exposed locations. When properly installed it should meet the following NEMA Type specifications.

Type 6 (with cover latched)
This is intended for indoor or outdoor use primarily to provide a degree of protection against solid foreign objects (falling dirt), hose-directed water, the entry of water during occasional temporary submersion at a limited depth and damage from external ice formation.

Type 6P (with cover screws installed)
This is intended for indoor or outdoor use primarily to provide a degree of protection against solid foreign objects (falling dirt), hose-directed water, the entry of water during prolonged submersion at a limited depth and damage from external ice formation.

Operation

The BGA244E operates the same manner as the regular BGA244. Configuration and control can be performed over either the front panel or one of the computer interfaces. Results are reported over the front panel, the computer interfaces or the analog outputs.

Because the BGA244E is inside of an enclosure it is less convenient to access the front panel. This is especially true if the enclosure is configured to Type 6P, with the cover screws installed. If regular access to the front panel is necessary, be sure to allow adequate clearance to open the cover. Often measurements are monitored remotely over one of the computer interfaces or analog outputs after the unit is configured.

Environment

The enclosure permits a harsher ambient environment, protecting the unit from dirt, water and ice. The same temperature, pressure, flow and gas requirements apply for the BGA244E as for the standard BGA244. No extra ventilation is required. Refer to *Operating Environment* (page 13) for details.

If the unit will not be exposed to prolonged submersion, insert the plugs into the cover screw holes to keep debris out. In this case the latch alone can adequately seal the cover to the box. Be sure to align the gasket in the cover with the sealing bead of the box when closing the cover. Fasten the latch to seal the box.

However if the unit will be exposed to prolonged submersion, you must install the four 10-32 x 0.75” cover screws to prevent leakage. Be sure to align the gasket in the cover with the sealing bead of the box when closing and fastening the cover latch. Insert and loosely tighten the four screws. Tighten screws in opposite corners to 10 inch-lbs (1.13 N-m) to seal the box.

Do not use PVC cement to connect fittings to the enclosure. Keep solvents that may react with polycarbonate away from the enclosure. This includes the following: acetone, ammonium hydroxide, ammonium nitrate, phenol, carbon tetrachloride, hydraulic brake fluid, lacquer thinner, Loctite, methylene chloride, perchlorethylene, potassium hydroxide, sodium hydroxide, toluene and xylene. Use light soapy water to clean the enclosure if necessary.

Access

Leave adequate clearance around the door if you will need to access the unit after installation. See the mechanical drawings (*Appendix C, Figure C-2 and C-3*) for dimensions. The door requires a minimum of 1.625" (41mm) clearance past the side of the box to fully open (to 90°). Be sure to leave adequate clearance to release the cover latch.

The gas fittings require a wrench to tighten or loosen. Be sure there is sufficient clearance, both in length and rotation. See the *Installation* section below for details.

The conduit fittings are tightened or loosened by hand. Be sure there is sufficient clearance, both in length and rotation. See the following *Installation* section for details.

Leave adequate clearance for the mounting flanges if used. If the flanges are to be fastened with bolts be sure to have sufficient wrench clearance, both in length and rotation.

Unpacking

Before You Open the Box

Do not remove the gas port dust caps until just prior to connecting the unit to your gas manifold to reduce the chance of contamination of the cell.

Read the *Installation* section on the following page prior to installing the BGA244E into your system.

Read the *Chapter 3: Operations Guide* and *Chapter 4: Applications Guide* in the main manual prior to operating the BGA244E.

Inspect all components of the SRS BGA244E upon unpacking. Report any damage to Stanford Research Systems immediately. Compare the contents of the shipping container to the list below and report any discrepancies.

What is included

Standard BGA244E

1. One BGA244E
2. One 6’ (1.8 m) USB cable
3. One Operation and Service Manual

Options

1. Option 1 Industrial Control Option (installed at Factory)
2. Option 2 No Display Option (installed at Factory)
3. Option T Pressure Transducer (installed at Factory)

Accessories

1. BGA-5 USB Power Supply
2. BGA-24 +24V Power Supply

Installation

Installation of mounting the BGA244E consists of the following steps. First mount the units in its operating location. Next connect the gas lines, conduit and cables. Plan the mounting of the BGA244E, gas pipes and electrical conduit prior to beginning installation. Be sure to clean out gas lines prior to connecting them to the BGA244E to avoid contamination.

Mounting

Whenever possible mount the BGA244E in a location that is free of large vibrations or impacts. If there are strong mechanical vibrations it may be necessary to mount the BGA244E in a different location.

Never rely on the inlet and outlet tubing or the conduit to support the weight of the BGA244E as it weighs about 9 lbs (4 kg) and is likely to damage either the tubing or itself.

Plan the location of the BGA244E, gas pipes and electrical conduit prior to mounting the unit. See the mechanical drawings (*Appendix C, Figure C-2 and C-3*) for the location of the gas fittings, electrical connectors and mounting points. There is no preferred gas flow direction; either gas port can be input or output.

The enclosure is a modified Integra Enclosure H8084HCF-6P. It includes hardware to mount it to a fixed location. The BGA244E can be installed in two different ways. The enclosure can be directly fastened to a mounting plate if the back of the mounting plate is accessible. Or mounting flanges can be installed on the BGA244E if the back of the mounting plate is not accessible.

Direct Mount

Mount the BGA244E from the rear of the mounting plate using four ¼”-20 UNC-B2 screws per the mechanical drawing (*Appendix C, Figure C-2*) The maximum penetration depth of the screws is 0.25” (6.35mm). Tighten the screws to 20 in-lbs (2.26 N-m).

Flange Mounting

Place the BGA244E face down on a flat, soft surface to avoid marring the cover. Place the mounting flanges over the square bosses along the top and bottom edges. Fasten the two flanges using the ¼”-20 flat head Philips head screws. Tighten the screws to 20 in-lbs (2.26 N-m).

Mount the BGA244E from either the front or rear using four ¼” screws or bolts per the mechanical drawing (*Appendix C, Figure C-3*). Mount to the ½” long slots only; the longer slots are not reinforced to support the weight of the BGA244E.

It may be necessary to remove the left side conduit nut to access screws in the lower flange. Alternatively bolts can be used to fasten the flanges. Do not over tighten screws or bolts to the flanges so as to not damage them.

Gas Fittings

The gas fittings are Swage 1/8”-27 NTP female-female couplings (SS-2-HGC). Follow the Swagelok Pipe Fitting Installation Instructions when connecting to the BGA244E. Swagelok recommends using a pipe thread sealant when assembling tapered threads. Use Loctite 565 thread sealant or equivalent. Avoid getting thread sealant on the enclosure as it may react with polycarbonate. Be sure to clean out gas lines prior to connecting them to the BGA244E to avoid contamination.

Conduit

The conduit connectors on the BGA244E are Arlington Snap^{2}IT Non-metallic Push-On Connectors (NMLT7). They are designed to connect to ¾” LFNC-B conduit (Liquid-tight, Flexible, Non-metallic Conduit, type B). Use the following procedures to install or remove the conduit.

- To install, simply push the liquid tight conduit over the ferrule end of the fitting. While pushing the connector, turn the conduit slightly clockwise to seat it.
- To remove, unscrew the nut and disassemble the connector. Re-assemble the connector for re-use.

Electrical

Make sure that the BGA244 is properly grounded. Depending on the installation, the power supply wiring and gas tubing may not be properly connected to earth ground. If necessary, connect the BGA244 chassis ground lug (C1) to a suitable earth ground.

Be sure that your installation confirms to all safety and electrical code requirements.

For CE compliance it is recommended that all power and I/O cables are shielded and grounded.

The BGA244 has no line voltages connections. Applying line voltage to any pin of any connector on the BGA244 will cause severe damage to the instrument and is a fire and smoke hazard.

The BGA244E has the same electrical connections that are in the standard BGA244. See the *Electrical Connections* (page 18) for more details on the electrical connections. Pay special attention to the following sections that may be more critical for BGA244E installations.

Electrical Noise Precautions

Installations may require long cable runs. Pay special attention to the grouping of wires in the conduits. Separate the power and computer interface wires from the analog IO wires if possible.

Electrical Connections

It may be more difficult to identify wires that have been pulled through conduits. Be sure to properly identify each wire before connecting it to the terminal strips. Be especially careful to properly identify the +24V wire, since connecting it to an incorrect pin can damage the unit.

Be sure to use the correct pinout for each connector. Failure to do so can result in damage to the BGA244. Pay special attention to C4 and C6, as they are adjacent and have the same number of pins.

> **Tip:** It's usually easier to remove the terminal strip from the BGA244 before connecting wires. Unplug the terminal strip by pulling straight back from the unit. Loosen the screws before inserting the wires. Make sure to observe the correct pinouts!

USB

The USB interface is not particularly well suited to power and control the BGA244E, although it can work in some circumstances. This would typically involve a USB adapter located near the BGA244E. A USB type B connector will fit through the ¾" conduit. It is more common to power the BGA244E over +24 V using the Industrial Control Interface (Option 1) and control it using either RS-232 or RS-422.

The maximum cable length for USB is about 5m (16.4'). A 5m cable should perform adequately for data communications, but powering the BGA244E over long cables is challenging. Voltage drops in the power wires may cause the voltage to drop below the minimum required voltage (4.75 V). Always use USB cables with 20 AWG power wires to minimize voltage drops. The BGA244 has been verified to operate with 3m USB cables with the appropriate power wires.

RS-232

Since a standard 9 pin RS-232 connector will not fit through the ¾" conduit, a DB9 to terminal strip adapter is provided with the BGA244E. Its pinout is listed below. The minimum RS-232 implementation is 3 wires: Rx, Tx and Ground. The CTS and RTS wires can be added to provide handshaking. The CD and DSR wires are pulled high to the asserted state and can be connected if required.

As with the other connections it is usually easier to detach the adapter from the BGA244 prior to connecting the wires. Reattach it to the BGA244 RS-232 port using the thumb screws after the wires are connected.

TABLE 25: C9 (RS-232 TERMINAL STRIP FOR BGA244E)

Pin	Signal		Pin	Signal
1	CD		1	Signal Ground
2	Rx		2	RI (nc)
3	Tx		3	DTR (nc)
4	DTR		4	CTS
5	GND		5	Tx
6	DSR		6	RTS
7	RTS		7	Rx
8	CTS		8	DSR
9	RI		9	CD
			10	Chassis Ground

Pressure Gauge

Option T (Pressure Transducer) comes pre-installed from the factory if ordered. This includes wiring and configuration. The Industrial Control Option (Option 1) must be installed to use Option T.

The transducer is wired to Analog Input 1. This means Analog Input 1 is not available as a general purpose input. Analog Input 1 is configured as follows. See *Pressure* (page 62) for additional details.

Analog Input 1	Current w/ Loop Power
Loop Power Voltage	15 V
Units	Absolute
Min (4 ma)	0 psi
Max (20 mA)	150 psi
Use as pressure gauge	Enabled
Analysis Pressure	Analog Input 1